Light Reflection and Refraction

Very Short Answer Type

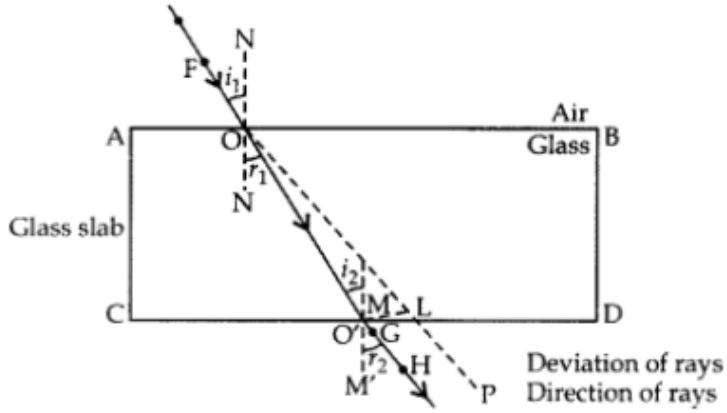
Question 1.
What is the magnification of the images formed by plane mirrors and why? (2015 D)
Answer:
The magnification of the image formed by a plane mirror is 1 because size of the image is equal to the size of the object.

Question 2.
What is meant by power of a lens? (2013 OD, 2015 D)
Answer:
The power of a lens is a measure of the degree of convergence or divergence of light rays falling on it. The power of a lens is defined as the reciprocal of its focal length in metres.
Power of a lens = 1/ Focal length (in m)
The SI unit of power is dioptre denoted by the letter D. One dioptre is the power of a lens whose focal length is 1 metre.

Short Answer Type I

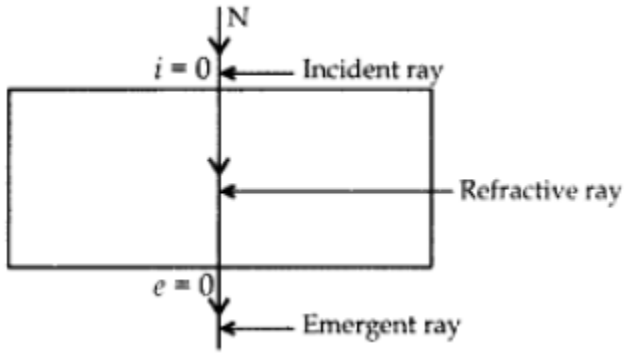
Question 1.
List four properties of the image formed by a concave mirror when object is placed between focus and pole of the mirror. (2012 D)
Answer:
Image is virtual, erect, magnified, i.e., bigger than the object and behind the mirror.

Question 2.
"A ray of light incident on a rectangular glass slab immersed in any medium emerges parallel to itself." Draw a labelled ray diagram to justify the statement. (2013 D)
Answer:



Angle of incidence = 55°
Angle of refraction = 40°
Angle of emergence = 55°
FO Incident ray
GH emergent ray

Question 3.
A ray of light falls normally on the surface of a transparent glass slab. Draw a ray diagram to show its path and also mark angle of incidence and angle of emergence. (2013 D)
Answer:



∠i = 0°; ∠r = 0°; ∠e = 0°

Question 4.
"A concave mirror of focal length can form a magnified erect as well as an inverted image of an object placed in front of it." Justify this statement stating the position of the object with respect to the mirror in each case for obtaining these images. (2012 OD)
Answer:

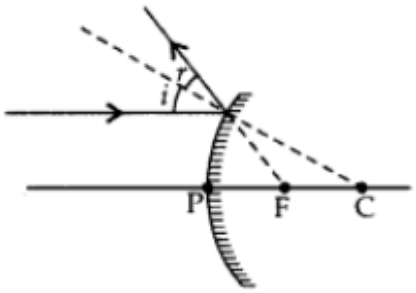
- When the object is placed at a distance less than 'f' (focal length) from the mirror, the image formed is virtual, magnified and erect.
- When the object is placed at a distance of 'f' (focal length) from the mirror, the image is real, inverted and highly magnified.
- When the object is placed at a distance more than 'f' (focal length) but less than '2f', the image formed is real, inverted and magnified.
- When the object is placed at the distance of '2f' from the mirror, the image is real, inverted and same size of the object.
- When the object is placed at a distance more than '2f' from the mirror, the image formed is real, inverted and diminished.

Question 5.
"A convex lens of focal length 'F' can form a magnified erect as well as inverted image." Justify this statement stating the position of the object with respect to the lens in each case for obtaining these images. (2013 OD)

Answer:
The type of image formed by a convex lens depends on the position of the object in front of the lens.

- When the object is placed between the optical centre and the focus (i.e., between O and F'), the image formed is behind the object (on the same side). It is virtual, magnified and erect.
- When the object is placed at the focus of a convex lens, the image formed is at infinity. It is real, inverted and highly magnified.
- When the object is placed between focus and the centre of curvature (i.e., between F' and 2F'), the image formed is beyond 2F. It is real, inverted and magnified.
- When the object is placed at the centre of curvature (i.e., at 2F'), the image formed is at 2F. It is real, inverted and of same size of the object.
- When the object is beyond 2F' (or beyond centre of curvature), the image formed is between F and 2F. It is real, inverted and diminished.
- When the object is at infinity, the image formed is at focus. It is real, inverted and much smaller than the object (highly diminished).

Question 6.
Draw a ray diagram to show the path of the reflected ray corresponding to an incident ray which is directed towards the principal focus of a convex mirror. Mark on it the angle of incidence and the angle of reflection. (2014 D)
Answer:



∠i = Angle of incidence
∠r = Angle of reflection

Question 7.
List two possible ways in which a concave mirror can produce a magnified image of an object placed in front of it. State the difference, if any, between these two images. (2014 OD)
Answer:
Case 1. Concave mirror can produce an erect, magnified, virtual image when the object is placed between pole and focus of the mirror
Case 2. Concave mirror also produces an inverted, magnified, real image when the object is placed between the focus and the centre of curvature.

Differences in the images of both the cases

Case 1	Case 2
(i) Image is virtual, i.e., the image is formed behind the mirror.	(i) Image is real, i.e., it is formed in front of the mirror (beyond C).
(ii) Image is erect.	(ii) Image is inverted.

Question 8.
"A concave mirror of focal length 15 cm can form a magnified erect as well as inverted image of an object placed in front of it." Justify this statement stating the position of the object with respect to the pole of the mirror in both cases for obtaining the images. (2014 OD)

Answer:
Case 1. When the object is placed between less than 15 cm from the pole, i.e., between the pole and the focus of a concave mirror, a magnified, erect and virtual image will be formed.

Case 2. When the object is placed between 15 to 30 cm, i.e., between the focus and the centre of curvature of the concave mirror, a magnified, inverted and real image will be formed.

Question 9.
List four characteristics of the images formed by plane mirrors. (2015 D)
Answer:
The characteristics of the images formed by plane mirrors are:

1. The image formed by a plane mirror is virtual and erect. It cannot be received on a screen.
2. The image formed by a plane mirror is of the same size as the object.

3. The image formed by a plane mirror is at the same distance behind the mirror as the object is in front of the mirror.
4. The image formed in a plane mirror is laterally inverted.

Question 10.
List four specific characteristics of the images of the objects formed by convex mirrors. (2015 D)
Answer:
The images of the objects formed by convex mirrors are always

1. Virtual
2. Erect
3. Diminished and
4. Formed behind the mirror between focus and pole of the mirror.

Question 11.
The absolute refractive indices of glass and water are 32 and 43 respectively. If the speed of light is 2×10^8 m/s, calculate the speed of light in (i) vacuum, (ii) water. (2015 OD)
Answer:
(i) Given: $v_g = 2 \times 10^8$ m/s (Speed of light in glass)
We know, Absolute Refractive Index of a Medium = Speed of light in Vacuum (c) Speed of light in the Medium

$$n_g = \frac{3}{2},\ n_w = \frac{4}{3} \quad \Rightarrow \quad n_g = \frac{c}{v_g} = c = n_g v_g \quad \Rightarrow \quad c = \frac{3}{2} \times 2 \times 10^8$$

$$\therefore \quad \mathbf{c = 3 \times 10^8\ m/s}$$

(ii) $n_w = \frac{4}{3}$ $\qquad c = 3 \times 10^8\ \text{m/s}$

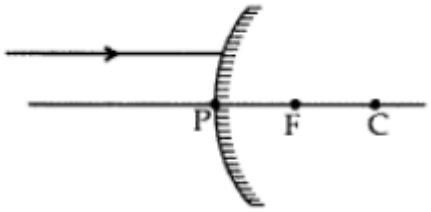
$$\Rightarrow \quad v_w = \frac{c}{n_w} = \frac{3 \times 10^8}{\frac{4}{3}} = \frac{3 \times 3 \times 10^8}{4} = \mathbf{2.25 \times 10^8\ m/s}$$

Question 12.
State two positions in which a concave mirror produces a magnified image of a given object. List two differences between the two images. (2016 D)
Answer:
The two positions are:
(i) When an object is placed between the pole (p) and focus (f) of a concave mirror, the image formed is larger than the object (or magnified).
(ii) When an object is placed between the focus (f) and centre of curvature (c) of a concave mirror, the image formed is larger than the object.

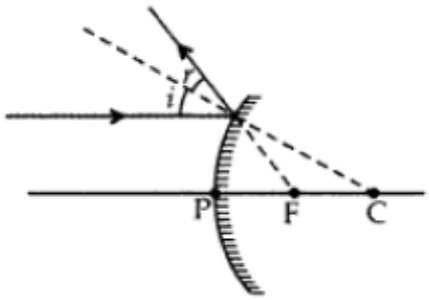
Difference between the two images

1. In case (i), the image is formed behind the mirror.	1. In case (ii), the image is formed beyond the centre of curvature.
2. In case (i), the image formed is virtual and erect.	2. In case (ii), the image formed is real and inverted.

Question 13.
A ray of light is incident on a convex mirror as shown. Redraw the diagram and complete the path of this ray after reflection from the mirror. Mark angle of incidence and angle of reflection on it. (2016 D)



Answer:



Question 14.
What is meant by power of a lens? What does its sign (+ve or -ve) indicate? State its S.I. unit. How is this unit related to focal length of a lens? (2016 D)
Answer:

- The power of a lens is a measure of the degree of convergence or divergence of light rays falling on it.
- +ve sign → converging lens/convex lens
  -ve sign → diverging lens/concave lens

- The SI unit of lens is dioptre. One dioptre is the power of a lens whose focal length is 1 metre.

Question 15.
"The magnification produced by a spherical mirror is -3". List four informations you obtain from this statement about the mirror/image. (2016 OD)
Answer:
Magnification produced by a spherical mirror, m = -3

- Image is 3 times magnified than the object.
- Image is inverted (as m has negative sign)
- Image is real.
- Nature of the mirror is concave.

Question 16.
The refractive indices of glass and water with respect to air are 3/2 and 4/3 respectively. if speed of light in glass is 2×10^8 m/s, find the speed of light in water.
Answer:

$$\text{Refractive index of a medium} = \frac{\text{Speed of light in air}}{\text{Speed of light in that medium}}$$

Given: $n_g = \frac{3}{2}$, $n_w = \frac{4}{3}$

Speed of light in glass = 2×10^8 m/s; Speed of light in water = v = ?

$$n_g = \frac{\text{Speed of light in air}}{\text{Speed of light in glass}} \Rightarrow \frac{3}{2} = \frac{\text{Speed of light in air}}{2\times10^8 \text{m/s}}$$

$$\therefore \text{Speed of light in air} = \frac{3}{2} \times 2 \times 10^8 = 3 \times 10^8 \text{ m/s}$$

$$n_w = \frac{\text{Speed of light in air}}{\text{Speed of light in water}} \Rightarrow \frac{4}{3} = \frac{3\times10^8 \text{m/s}}{v}$$

$$3 \times 10^8 \times \frac{3}{4} = v \Rightarrow v = 2.25 \times 10^8 \text{ m/s}$$

$\therefore$ Speed of light in water = 2.25×10^8 m/s

Question 17.
An object is placed at a distance of 30 cm in front of a convex mirror of focal length 15 cm. Write four characteristics of the image formed by the mirror. (2017 D)
Answer:
Four characteristics of the image formed are:

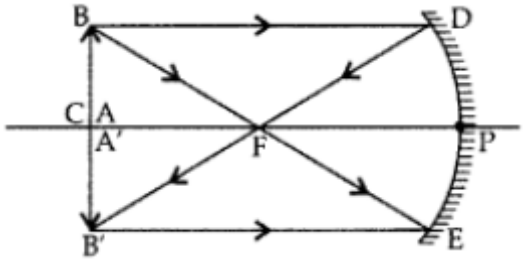
- Image is erect.

- Image is virtual.
- Image is diminished in size.
- The image is formed behind the mirror between P & F points of the mirror.
- The image is laterally inverted.

Question 18.
A student places a candle flame at a distance of about 60 cm from a convex lens of focal length 10 cm and focuses the image of the flame on a screen. After that he gradually moves the flame towards the lens and each time focuses the image on the screen.
(a) In which direction-toward or away from the lens, does he move the screen to focus the image?
(b) How does the size of the image change?
(c) How does the intensity of the image change as the flame moves towards the lens?
(d) Approximately for what distance between the flame and the lens, the image formed on the screen is inverted and of the same size? (2017 D)
Answer:
(a) He will move the screen away from the lens to focus the image.
(b) Size of the image goes on increasing.
(c) Intensity of image goes on decreasing.
(d) About 20 cms.

Short Answer Type II

Question 1.
Draw the ray diagram and also state the position, the relative size and the nature of image formed by a concave mirror when the object is placed at the centre of curvature of the mirror.
Answer:
When the object is at the centre of curvature of a concave mirror, i.e., point C:



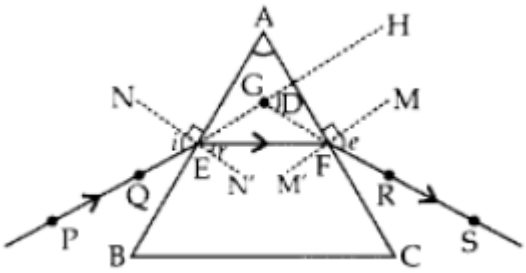
The image formed is

- real,
- inverted,
- same size as the object at C, and
- at C.

Question 2.
Define, 'refractive index of a transparent medium'. What is its unit? Which has a higher refractive index – glass or water? (2011 D)
Answer:

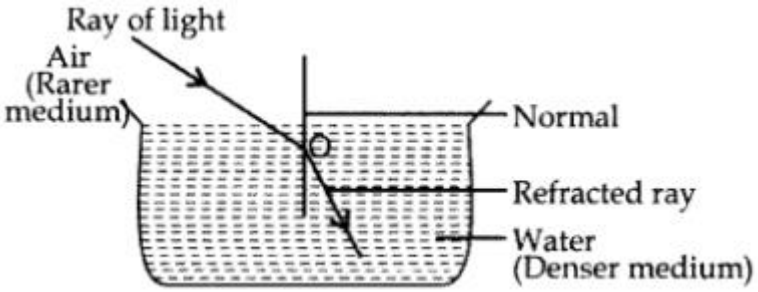
- The light bending ability of a transparent medium is called the refractive index of that medium.
- The ratio of speed of light in vacuum to the speed of light in a medium is called the refractive index of that medium.
  refractive index (of a medium) = Speed of light in vacuum / Speed of light in medium
- Since refractive index is a ratio of two similar quantities therefore it has no units.
- The refractive index of glass is more than water.

Question 3.
Draw a ray diagram to show the refraction of light through triangular glass prism and mark angle of deviation on it. (2011 D)
Answer:
Refraction of light through triangular glass prism:



PF – Incident ray
EF – Refracted ray
FS – Emergent ray
∠A – Angle of the prism
∠i – Angle of incidence
∠r – Angle of refraction
∠e – Angle of emergence
∠D – Angle of deviation

Question 4.
A ray of light travelling in air enters obliquely into water. Does the light ray bend towards or away from the normal? Why? Draw a ray diagram to show the refraction of light in this situation. (2011 D)
Answer:

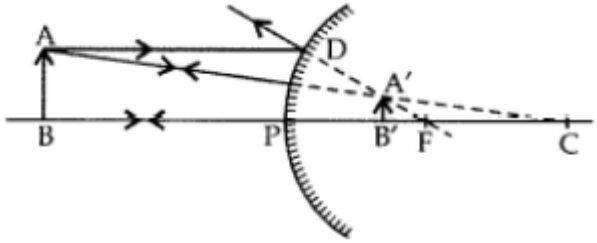


When a ray of light travelling in air enters obliquely into water, the light ray will bend towards the normal. Because when a ray of light travels obliquely from rarer medium to denser medium, it will bend towards the normal.

Question 5.
(i) "The refractive index of diamond is 2.42". What is the meaning of this statement?
(ii) Name a liquid whose mass density is less than that of water but it is optically denser than water. (2011 D)
Answer:
(i) The refractive index of diamond is 2.42. It means that the ratio of the speed of light in air and the speed of light in diamond is equal to 2.42.
Higher is the refractive index of a medium, lower is the speed of light in that medium. Because the refractive index of diamond is very high, therefore the speed of light in diamond is very low.

(ii) Kerosene has the mass density less than water but it is optically denser than water.

Question 6.
An object is placed between infinity and the pole of a convex mirror. Draw a ray diagram and also state the position, the relative size and the nature of the image formed. (2011 OD)
Answer:
Position, size and nature of image:
Image formed by a convex mirror is virtual, diminished, erect and behind the mirror between its P (pole) and F (focus) point.



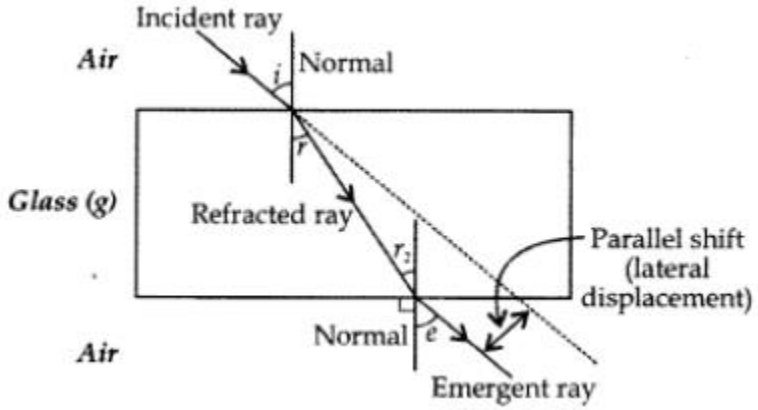
Question 7.
What is the principle of reversibility of light? Show that the incident ray of light is

parallel to the emergent ray of light when light falls obliquely on a side of a rectangular glass slab. (2011 OD)

Answer:

Principle of reversibility of light. Refractive index for light going from medium 1 to medium 2 is equal to the reciprocal of refractive index for light going from medium 2 to medium 1.

$_1\eta_2 = {}_2\eta_1$



According to Snell's law

$_a\eta \sin i = {}_8\eta \sin r_1$ .....(i)

Similarly, $_8\eta \sin r_2 = {}_a\eta \sin e$ .....(ii)

$r_2 = r_1$ because glass slab is rectangular and therefore the two normals are parallel.

r_1 and r_2 are alternate interior angles.

Comparing (i) and (ii), we get

$_a\eta \sin i = {}_a\eta \sin e$

$\sin i = \sin e \Rightarrow i = e$

∴ angle of incidence is equal to the angle of emergence when a ray of light falls obliquely on a rectangular glass slab.

Question 8.

The image of a candle flame placed at a distance of 45 cm from a spherical lens is formed on a screen placed at a distance of 90 cm from the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 2 cm, find the height of its image. (2012 D)

Answer:

Object distance, u = -45 cm, Image distance, v = +90 cm (real) Focal length, f = ?, Nature of lens = ?, Height of the object, h_1 = 2 cm, Height of the image, h_2 = ?

According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{90} - \frac{1}{-45} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{90} + \frac{1}{45} = \frac{1+2}{90} = \frac{\cancel{3}^{1}}{\cancel{90}_{30}} = \frac{1}{30}$$

∴ f = 30 cm

The positive sign of f shows that the given lens is a convex lens of focal length 30 cm.

Magnification,

$$m = \frac{v}{u} = \frac{+90^2}{-45} = -2$$

$\Rightarrow h_2h_1 = -2 \Rightarrow h_22 = -2$
$\therefore h = -4$
The height of the image is 4.
The negative sign shows that this image is in the downward direction below the axis, i.e., image is inverted.

Question 9.
State the type of mirror preferred as (i) rear view mirror in vehicles, (ii) shaving mirror. Justify your answer giving two reasons in each case. (2012 D)
Answer:
(i) Convex mirror is used as rear view mirror in vehicles because the image formed in a convex mirror is highly diminished thus a convex mirror gives a wide field of view. Therefore a convex mirror enables a driver to view a much larger area of the traffic behind him.

(ii) Concave mirror is used as shaving mirror because when face is held within the focus of a concave mirror, an enlarged image of the face is seen in the concave mirror.

Question 10.
The image of a candle flame placed at a distance of 36 cm from a spherical lens is formed on a screen placed at a distance of 72 cm from the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 2.5 cm, find the height of the image. (2012 D)
Answer:
Object distance, u = -36 cm,
Images distance, v = +72 cm
[+ve sign is due to the image being formed on the screen hence it is real]
Focal length, f = ?, Nature of the lens = ?
Height of the object, h_1 = 2.5 cm, Height of the image, h_2 = ?
According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{72} - \frac{1}{-36} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{72} + \frac{1}{36} = \frac{1+2}{72} = \frac{\cancel{3}^{1}}{\cancel{72}_{24}} = \frac{1}{24}$$

$\therefore f = +24 \Rightarrow$ +ve sign off shows that the lens is convex having focal Length 24 cm.

Magnification, $m = \frac{v}{u} = \frac{72^2}{36} = -2$

Formula: $m = \frac{h_2}{h_1} = \frac{h_2}{2.5} = -2$

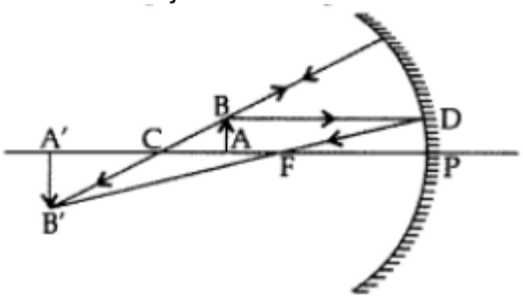
$\Rightarrow h_2 = -2 \times 2.5 = -5$ cm

- -ve sign of h_2 shows that the image is inverted.
- Thus an inverted, magnified, 5 cm long image is formed on the screen.

Question 11.
To construct ray diagram we use two light rays which are so chosen that it is easy to know their directions after reflection from the mirror. List these two rays and state the path of these rays after reflection. Use these rays to locate the image of an object placed between centre of curvature and focus of a concave mirror. (2012 OD)
Answer:
Rays used and their path after reflection:
(i) A ray parallel to the principal axis after reflection this ray will pass through the principal focus in case of a concave mirror or appear to diverge from the principal focus in case of a convex mirror.

(ii) A ray passing through the centre of curvature of a concave mirror or directed in the direction of the centre of curvature of a convex mirror, after reflection, is reflected back along the same path.

When the object is between centre of curvature C and focus F of mirror:



The image formed is

- real,
- inverted,
- magnified, and
- beyond C.

Question 12.
A 4 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 24 cm. The distance of the object from the lens is 16 cm. Find the

position, size and nature of the image formed, using the lens formula. (2012 OD)

Answer:

Height of the object, h_1 = 4 cm

Convex lens:

Focal length, f = +24 cm, Object distance, u = -16 cm, Image distance, v = ?

Height of the image, h_2 = ?, Nature of the image = ?v

According to lens formula:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} - \frac{1}{-16} = \frac{1}{24} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{16} = \frac{1}{24}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{24} - \frac{1}{16} = \frac{2-3}{48} = \frac{-1}{48} \quad \therefore \quad v = -48 \text{ cm}$$

- The image is formed at a distance of 48 cm from the convex lens.
- The minus sign for image distance shows that the image is formed on the left side of the convex lens.
- Only virtual image is formed on the left hand side.

According to formula: m = $h_2 h_1$, m = vu

$$\frac{h_2}{h_1} = \frac{v}{u} \quad \Rightarrow \quad \frac{h_2}{4} = \frac{\not{-}48}{\not{-}16} = 3$$

$\therefore h_2 = 3 \times 4 = 12$ cm.

Thus a magnified (12 cm high), virtual and erect image is formed.

Question 13.

A 2.4 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 18 cm. The distance of the object from the lens is 12 cm. Find the position, size and nature of the image formed, using the lens formula. (2012 OD)

Answer:

h_1 = +2.4 cm (upright) (Concave lens) v = ? h_2 = ?

f = +18 cm (for convex lens) u = -12 cm Nature of the image = ?

According to lens formula:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} - \frac{1}{-12} = \frac{1}{18} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{12} = \frac{1}{18}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{18} - \frac{1}{12} = \frac{2-3}{36} = \frac{-1}{36} \quad \Rightarrow \quad v = -36 \text{ cm}$$

- Image is formed at a distance of 36 cm from the convex lens.
- The negative (-) sign of v shows that the image is formed on the left hand side of the convex lens. Only virtual image is formed on the left hand side

$$m = \frac{v}{u} = \frac{\cancel{-36}^{3}}{\cancel{-12}} = 3 \quad \Rightarrow \quad m = \frac{h_2}{h_1} = \frac{h_2}{2.4} \quad \Rightarrow \quad \frac{h_2}{2.4} = 3$$

$\Rightarrow h_2 = 3 \times 2.4 = 7.2$ cm

- The height of the image is 7.2 cm.
- The positive (+) sign shows that the image is formed above the axis. Thus the image is virtual and erect.

Question 14.
A 5 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 12 cm. The distance of the object from the lens is 8 cm. Using the lens formula find the position, size and nature of the image formed. (2012 OD)
Answer:
f = +12 cm (for convex lens), h_1 = 5 cm, u = -8cm
v = ?, h_2 = ?, Nature of the image = ?
According to lens formula:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} - \frac{1}{-8} = \frac{1}{12} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{8} = \frac{1}{12}$$

$$\Rightarrow \frac{1}{v} = \frac{1}{12} - \frac{1}{8} = \frac{2-3}{24} = \frac{-1}{24} \quad \Rightarrow \quad v = -24 \text{ cm}$$

- Image is formed at a distance of 24 cm from the convex lens.
- The negative (-) sign of v shows that the image is formed on the left hand side of the convex lens and only virtual image is formed on the left hand side.

A virtual image is formed at 24 cm from the lens.

$$\therefore \ m = \frac{v}{u} = \frac{\cancel{24}^{3}}{\cancel{8}} = 3 \quad \Rightarrow \quad m = \frac{h_2}{h_1} \quad \Rightarrow \quad \frac{h_2}{5} = 3$$

$\therefore h_2 = 3 \times 5 = 15$ cm

- Thus size of the image is 15 cm.
- The positive (+) sign shows that the image is formed above the axis.
- Thus a virtual, magnified and erect image is formed.

Question 15.
The image of a candle flame placed at a distance of 30 cm from a spherical lens is formed on a screen placed at a distance of 60 cm from the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 2.4 cm, find the height of its image. (2012 D)
Answer:
Object distance, u = -30 cm,
Image distance, v = +60 cm

[+ve sign is due to the image formed on the screen, hence it is real]
f = ?, Type of lens = ?
Height of the object, h_1 = 2.4 cm, Height of the image, h_2 = ?
According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{60} - \frac{1}{-30} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{60} + \frac{1}{30} = \frac{1+2}{60} = \frac{\cancel{3}^{1}}{\cancel{60}_{20}} = \frac{1}{20}$$

∴ f = + 20cm
The positive (+ve) sign of/shows that the lens is convex having focal length 20 cm.
Now Magnification,

$$m = \frac{v}{u} = \frac{\cancel{60}^{2}}{\cancel{-30}} = -2$$

The negative (-ve) sign of h_2 shows that the image is inverted.

Question 16.
Mention the types of mirrors used as (i) rear view mirrors, (ii) shaving mirrors. List two reasons to justify your answers in each case. (2013 D)
Answer:
(i) Convex mirror is used as rear view mirror in vehicles because

- It always produces an erect image of the objects;
- The image formed in a convex mirror is highly diminished thus it gives a wide field of view.

(ii) Concave mirrors are used as shaving mirrors because

- when the face is held within the focus of a concave mirror, then an enlarged image of the face is seen in the concave mirror. This helps in making a smooth shave.

Question 17.
An object of height 6 cm is placed perpendicular to the principal axis of a concave lens of focal length 5 cm. Use lens formula to determine the position, size and nature of the image if the distance of the object from the lens is 10 cm. (2013 D)
Answer:
Height of the object, h_1 = 6 cm, Focal length of the concave mirror, f = -5 cm
Position of the image, v = ?, Size of the image, h_2 = ?
Object distance, u = -10 cm

According to lens formula:

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad \frac{1}{v}-\frac{1}{-10}=\frac{1}{-5} \quad \Rightarrow \quad \frac{1}{v}+\frac{1}{10}=\frac{-1}{5}$$

$$\Rightarrow \frac{1}{v}=\frac{-1}{5}-\frac{1}{10}=\frac{-2-1}{10}=\frac{-3}{10} \quad \therefore \quad v=\frac{-10}{3}=\mathbf{-3.3\ cm}$$

$$\frac{h_2}{h_1}=\frac{v}{u} \quad \Rightarrow \quad \frac{h_2}{6}=\frac{\frac{10}{3}}{10} \quad \Rightarrow \quad \frac{h_2}{6}=\frac{10}{3\times 10}=\frac{1}{3}$$

$$\Rightarrow h_2=\frac{6}{3} \quad \therefore \quad h_2=\mathbf{+2\ cm}$$

Thus the image is formed at a distance of 3.3 cm from the concave lens. The negative (-) sign for image distance shows that the image is formed on the left side of the concave lens (i.e., virtual). The size of the image is 2 cm and the positive (+) sign for hand image shows that the image is erect.
Thus a virtual, erect, diminished image is formed on the same side of the object (i.e., left side).

Question 18.
An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. Use lens formula to determine the position, size and nature of the image if the distance of the object from the lens is 20 cm. (2013 D)
Answer:
Height of the object, h_{21} = 5 cm, Focal length of the concave lens, f = -10 cm
Position of the object, v = ?, Size of the object, h_2 = ?
Object distance, u = -20 cm,

According to lens formula:

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad \frac{1}{v}-\frac{1}{-20}=\frac{1}{-10} \quad \Rightarrow \quad \frac{1}{v}+\frac{1}{20}=\frac{-1}{10}$$

$$\Rightarrow \frac{1}{v}=\frac{-1}{10}-\frac{1}{20}=\frac{-2-1}{20}=\frac{-3}{20} \quad \therefore \quad v=\frac{-20}{3}=-6.67 \quad \therefore \quad \textbf{Image distance = -6.67cm}$$

The negative (-) sign for image distance shows that image is formed on the left side of the concave lens. So the image is virtual.

$$\text{Magnification, } m=\frac{v}{u},\ m=\frac{h_2}{h_1} \quad \therefore \quad m=\frac{\frac{20}{3}}{10}=\frac{20^2}{10\times 3}=\frac{+2}{3}=0.67$$

$$\Rightarrow \frac{h_2}{h_1}=\frac{v}{u} \quad \therefore \quad h_2=\frac{h_1\times v}{u}=\frac{5\times -20}{3\times -20}=\frac{5}{3} \quad \Rightarrow \quad \mathbf{m = +1.66\ cm}$$

Since $h_2 < h_1$ therefore image is diminished. The positive (+) sign for the magnification shows that image is erect and virtual.

Question 19.
An object of height 4 cm is kept at a distance of 30 cm from a concave lens. Use lens formula to determine the image distance, nature and size of the image formed if focal length of the lens is 15 cm. (2013 D)

Answer:
Height of the object, h_1 = 4 cm, Object distance, u = -30 cm (It is to the left of the lens)
Focal length of concave lens, f = -15cm, Image distance, v = ?,
nature of the image = ? Image height, h_2 = ?,

According to lens formnla:

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} - \frac{1}{-30} = \frac{1}{-15} \quad \Rightarrow \quad \frac{1}{v} + \frac{1}{30} = \frac{-1}{15}$$

$$\Rightarrow \frac{1}{v} = \frac{-1}{15} - \frac{1}{30} = \frac{-2-1}{30} = \frac{-3^{1}}{30_{10}} = \frac{1}{10} \quad \therefore \quad v = \mathbf{-10\ cm}$$

Thus the image is formed at a distance of 10 cm from the concave lens.
The negative (-) sign for image distance shows the image is formed on the left side of the concave lens, i.e., it is virtual.

$$\text{Magnification, } m = \frac{v}{u},\ m = \frac{h_2}{h_1}$$

$$\therefore \frac{h_2}{h_1} = \frac{v}{u} \quad \Rightarrow \quad \frac{h_2}{4} = \frac{-10}{-30} = \frac{1}{3} \quad \Rightarrow \quad h_2 = \frac{1}{3} \times 4 = \frac{4}{3} = \mathbf{+1.33\ cm}$$

Thus a 1.33 cm high image is formed and positive (+) sign of h_2 shows that image is erect.
Thus image distance = 10 cm, image height = 1.33 cm.
Nature of the image is virtual and erect.

Question 20.
Name the type of mirror used (i) by dentists and (ii) in solar furnaces. Give two reasons why such mirrors are used in each case. (2013, 2016 OD)

Answer:
(i) Concave mirrors are used by dentists to see the large images of the teeth of patients because when a tooth is within the focus of a concave mirror, then an enlarged image of the tooth is seen in the concave mirror. Thus it becomes easier to locate the defect in the tooth.

(ii) Large concave mirrors are used in solar furnaces as reflectors. Solar furnace is placed at the focus of the concave reflector which focusses the Sun's heat rays on the furnace due to which the solar furnace gets very hot. Even steel can be melted in this solar furnace.

Question 21.
A student focussed the image of an object on a white screen using a converging lens. He noted down the positions of the object, screen and the lens on a scale as given below:
Position of object = 10.0 cm; Position of lens = 50.0 cm; Position of screen = 90.0 cm
(a) Find the focal length of the converging lens.
(b) Find the position of the image if the object is shifted towards the lens at a position of 30.0 cm.
(c) State the nature of the image formed if the object is further shifted towards the lens. (2013 OD)

Answer:
Object distance, u = -40 cm, Image distance, v = (90 – 50) = +40 cm
(a) Focal length of converging lens, f = ?

According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{40} - \frac{1}{-40} = \frac{1}{40} + \frac{1}{40} \quad \Rightarrow \quad \frac{1}{f} = \frac{2}{40} = \frac{1}{20}$$

∴ Focal length of converging lens, f = +20 cm

(b) If u = -20 cm (Object is shifted from 10 cm to 30 cm with respect to 50 cm)
f = +20 cm

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{20} + \frac{1}{-20} = \frac{1}{20} - \frac{1}{20} = 0 \quad \Rightarrow \quad \frac{1}{v} = 0$$

⇒ v = 0
∴ v = ∞ (∵Reciprocal of 0 is ∞)
So image is formed at infinity.
(c) If the object is shifted from 30 cm towards 50 cm, the object lies between the focus and optical centre of the lens. Then the image formed will be behind the object, virtual, erect and enlarged (larger than the object).

Question 22.
A student focussed the image of a candle flame on a white screen using a convex lens. He noted down the positions of the candle flame, screen and the lens as given below: (2013 OD)
Position of the candle flame = 12.0 cm; Position of the lens = 50.0 cm; Position of the screen = 88.0 cm
(i) Find the focal length of the convex lens.
(ii) Find the position of the image of the candle flame if it is shifted towards the lens at a position of 31.0 cm.
(iii) State the nature of the image formed if the candle flame is further shifted towards the lens.

Answer:
Position of the candle flame = 12 cm,
Position of the lens = 50 cm
Position of the screen = 88 cm, Object distance,
u = 50 – 12 = -38 cm
Image distance, v = 88 – 50 = +38 cm (+ sign for real image as the image is formed on the screen)

(i) Focal length of convex lens, f = ?
According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{38} - \frac{1}{-38}$$

$$\Rightarrow \frac{1}{f} = \frac{1}{38} + \frac{1}{38} = \frac{2^{1}}{38_{19}} = \frac{1}{19} \quad \Rightarrow \quad f = 19$$

∴ Focal length of the convex lens, f = +19 cm
+ve sign shows the converging lens, i.e., convex lens.

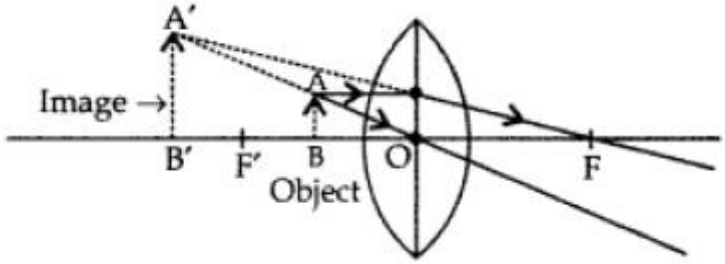
(ii) v = ?, f = +19 cm, u = (50 – 31) = -19 cm

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{19} + \frac{1}{-19} = \frac{1}{19} - \frac{1}{19} = 0$$

$$\Rightarrow \frac{1}{v} = 0 \quad \therefore \quad v = \infty \ (\because \text{Reciprocal of } 0 \text{ is } \infty)$$

So image is formed at infinity.

(iii) When the candle flame lies between 50 cm to 31 cm, i.e., less than 19 cm, the image will be virtual, erect, magnified and behind the object.

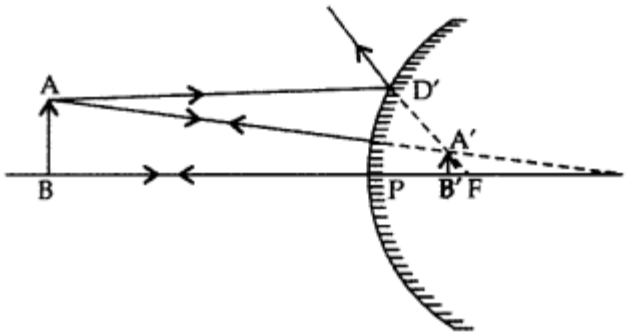


Question 23.
A spherical mirror ‘A’ always forms an erect image of an object and another spherical mirror ‘B’ forms erect as well as inverted image of an object. State with reasons the type of spherical mirrors ‘A’ and ‘B’ and draw ray diagrams showing formation of images to justify your answer. (2013 OD)
Answer:
Mirror ‘A’ is a convex mirror as this mirror always forms an erect and virtual image.

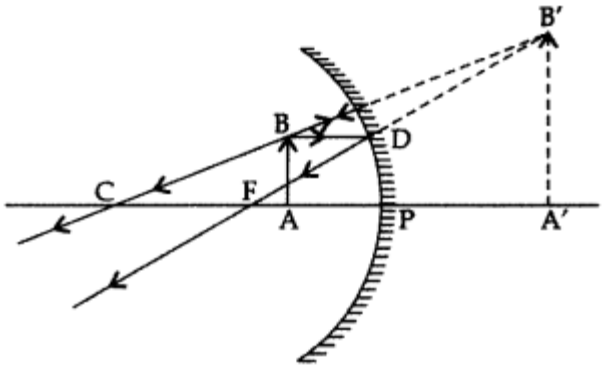
When an incident ray is parallel to the principal axis, the reflected ray appears to be coming from the focus and when incident ray moves towards the centre of curvature, the reflected ray retraces the path.

These two rules show that the reflected rays are diverging and when produced backward, the rays appear to meet. Thus, this mirror always produces a virtual image which is always erect.

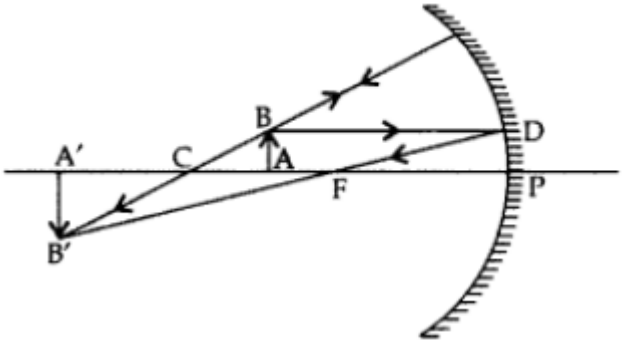
Mirror 'B' is a concave mirror. The nature, position and size of the image formed by a concave mirror depends on the position of the object in relation to points P(Pole), F(focus) and C (centre of curvature) of the mirror.

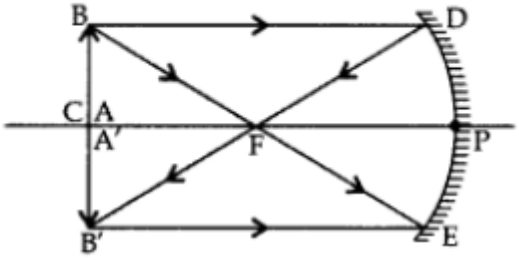


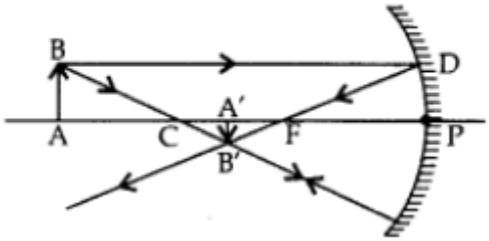
Case 1. When the object is placed between P and F – the two reflected rays (one passes through the focus and other retraces through centre of curvature) are diverging and appear to meet in backward direction. This produces a virtual and erect image.



Case 2. As the object moves away from the mirror beyond F the two reflected rays actually meet below the principal axis which produces a real and inverted image.







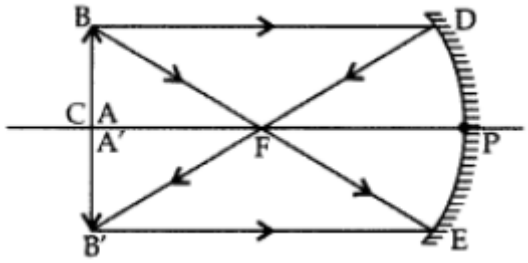
Question 24.
A spherical mirror produces an image of magnification -1 on a screen placed at a distance of 50 cm from the mirror.
(a) Write the type of mirror.
(b) Find the distance of the image from the object.
(c) What is the focal length of the mirror?
(d) Draw the ray diagram to show the image formation in this case. (2014 D)

Answer:
If magnification, m = -1; v = 50 cm
If the magnification has minus sign, then the image is real and inverted.
∴ v = -50 (for real image) ∵ m = $-\frac{v}{u}$
⇒ -1 = $-\frac{(-50)}{u}$
u = -50 cm
(a) Since image is formed on the screen therefore the mirror formed real image which is formed by concave mirror only.
(b) Image distance = 50 cm in front of the mirror.
(c)

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{-50}+\frac{1}{-50} \quad \Rightarrow \quad \frac{1}{f}=-\frac{1}{50}-\frac{1}{50} \quad \Rightarrow \quad \frac{-2}{50}=\frac{-1}{25}$$

$\therefore f = -25$ cm

(d)



Question 25.
A spherical mirror produces an image of magnification -1 on a screen placed at a distance of 40 cm from the mirror: (2014 D)
(i) Write the type of mirror.
(ii) What is the nature of the image formed?
(iiI) How far is the object located from the mirror?
(iv) Draw the ray diagram to show the image formation in this case.
Answer:

- Spherical mirror
- m = -1
- Image is formed on a screen
  Image distance, v – 40 m

(i) Concave mirror
(ii) Real image (as it is formed on the screen)
(iii) m = -1
$m = -\frac{v}{u}$
$\Rightarrow -1 = -\frac{(-40)}{u}$
$\Rightarrow -u = +40$
$\Rightarrow u = -40$ cm
∴ Object is placed at 40 cm from the mirror.

Question 26.
A student wants to project the image of a candle flame on a screen 60 cm in front of a mirror by keeping the flame at a distance of 15 cm from its pole.
(i) Write the type of mirror he should use.
(ii) Find the linear magnification of the image produced.
(iii) What is the distance between the object and its image?
Draw a ray diagram to show the image formation in this case. (2014 OD)
Answer:
Concave mirror
Linear magnification = $-\frac{\text{Image distance}}{\text{Object distance}}$
$\Rightarrow m = -\frac{v}{u}$
Object distance Object distance, u = -15 (u is always negative)

Image distance, v = -60 (n is negative for real image)

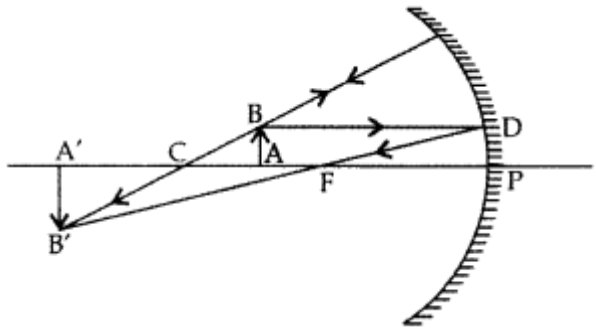
$m = -\frac{(-60)}{(-15)}$

∴ m = -4

The minus sign in magnification shows that the image formed is real and inverted.

(iii) Distance between object and its image = 45 cm

(iv) Ray diagram:



The image formed is real, inverted, magnified and beyond 2f.

Question 27.

Draw a ray diagram to show the path of the refracted ray in each of the following cases: A ray of light incident on a concave lens is

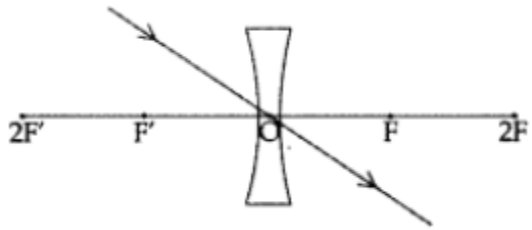
(i) passing through its optical centre.

(ii) parallel to its principal axis.

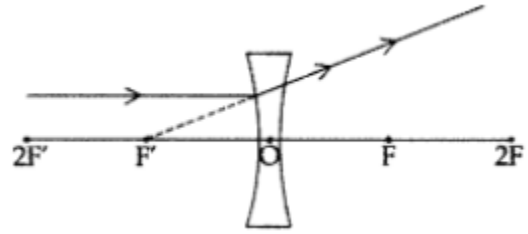
(iii) directed towards its principal focus.

Answer:

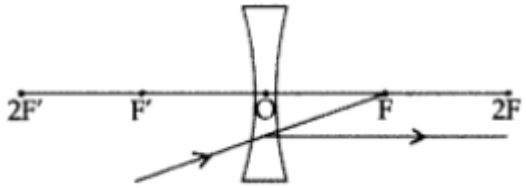
(i) A ray of light passing through optical centre of a concave lens. An incident ray passing through the optical centre of a lens (concave or convex) goes straight after refraction.



(ii) Light ray parallel to principal axis.

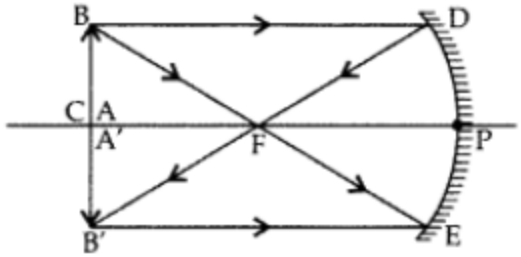


(iii) A ray of light directed towards principal rocus.



Question 28.
A student wants to project the image of a candle flame on a screen 48 cm in front of a mirror by keeping the flame at a distance of 12 cm from its pole.
(a) Suggest the type of mirror he should use.
(b) Find the linear magnification of the image produced.
(c) How far is the image from its object?
(d) Draw ray diagram to show the image formation in this case. (2014 OD)

Answer:
(a) Concave mirror as only concave mirror produces the real image.
(b) Linear magnification = $-\frac{\text{Image distance}}{\text{Object distance}}$
$\Rightarrow m = -\frac{v}{u}$
Object distance, u = -12 (u is always negative)
Image distance, v = -60 (v is negative for real image)
$m = -\frac{(-48)}{(-12)}$
$\therefore m = -4$
The minus sign in magnification shows that the image formed is real and inverted.
(c) The image is formed at a distance of 36 cm from the object.
(d) Ray diagram:



Question 29.
A student wants to project the image of a candle flame on a screen 90 cm in front of a mirror by keeping the flame at a distance of 15 cm from its pole.
(a) Suggest the type of mirror he should use.
(b) Determine the linear magnification in this case.
(c) Find the distance between the object and its image.
(d) Draw ray diagram to show the image formation in this case. (2014 OD)

Answer:
(a) Concave mirror
(b) Linear magnification = $-\frac{\text{Image distance}}{\text{Object distance}}$
$\Rightarrow m = -\frac{v}{u}$
Object distance, u = -15 (u is always negative)

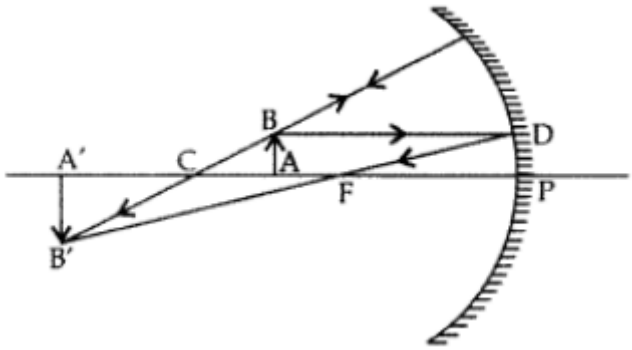
Image distance, v = -90 (-ve sign as the image is formed in front of the mirror on the screen)

m = $\frac{-(-90)}{(-15)}$

∴ m = -6

(c) The distance between the object and its image is 75 cm.

(d) Ray diagram:



Question 30.

To construct a ray diagram we use two rays of light which are so chosen that it is easy to determine their directions after reflection from the mirror. Choose these two rays and state the path of these rays after reflection from a concave mirror. Use these two rays to find the nature and position of the image of an object placed at a distance of 15 cm from a concave mirror of focal length 10 cm. (2015 D)

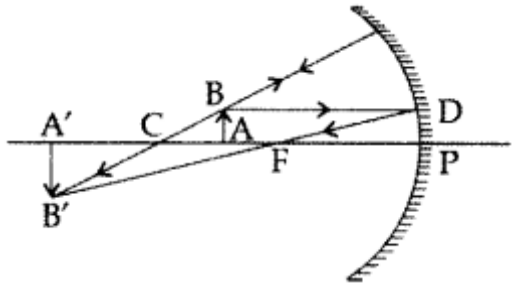
Answer:

Ray 1. When an incident ray of light is parallel to the principal axis of a concave mirror, its reflected ray must pass through the principal focus of the concave mirror.

Ray 2. A ray passing through the 'C' point of a concave mirror after reflection will be reflected back on the same path.

Focal length = 10 cm; Then centre of curvature, C = 20 cm

Object is placed at 15 cm, i.e., between F & C When the object is between F and C (centre of curvature):



The image formed is real, inverted and magnified.

It is formed beyond C.

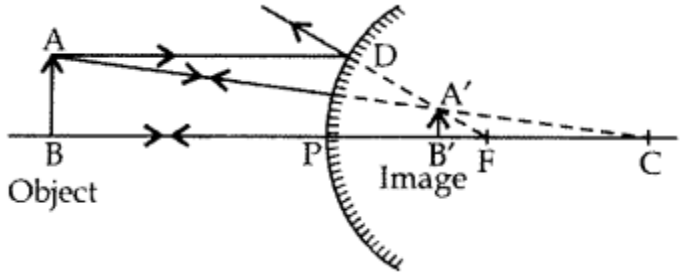
Question 31.

If the image formed by a mirror for all positions of the object placed in front of it is always erect and diminished, what type of mirror is it? Draw a ray diagram to justify

your answer. Where and why do we generally use this type of mirror? (2015 OD)

Answer:

Convex mirror always forms an erect, virtual and diminished image for all positions of the object placed in front of it.



Uses:

(i) Convex mirrors are used as rear-view mirrors in vehicles to see the traffic at the rear side (or back side) because – (i) a convex mirror always produces an erect image of the object; (ii) the image formed in a convex mirror is highly diminished due to which a convex mirror gives a wide field of view.

(ii) Big convex mirrors are used as 'shop security mirrors'. By installing a big convex mirror at a strategic point in the shop, the shop owner can keep an eye on the customer to look for thieves and shoplifters among them as convex mirrors always form a virtual, diminished and erect image.

Question 32.

An object of height 5 cm is placed perpendicular to the principal axis of a concave lens of focal length 10 cm. If the distance of the object from the optical centre is 20 cm, determine the position, nature and size of the image formed using the lens formula. (2015 OD)

Answer:

Object height, h_1 = +5 cm, Focal length, f_1 = -10 cm, Object distance, u = -20 cm
Image distance, v = ?, Nature of the image = ?, Image height, h_2 = ?

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{v} = \frac{1}{f} + \frac{1}{u} = \frac{1}{(-10)} + \frac{1}{(-20)} = \frac{-1}{10} - \frac{1}{20}$$

$$\Rightarrow \frac{1}{v} = \frac{-2-1}{20} = \frac{-3}{20} \quad \therefore \quad v = \frac{-20}{3} = \mathbf{-6.67\ cm}$$

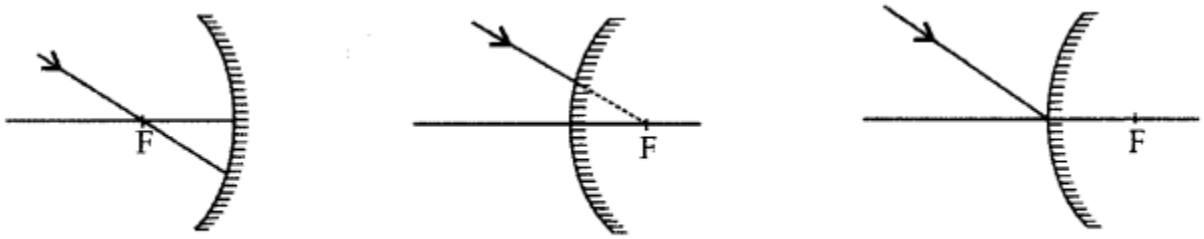
Negative sign of v shows that image is formed on the same side of the object, i.e., virtual.

$$\frac{h_2}{h_1} = \frac{v}{u} \quad \Rightarrow \quad \frac{h_2}{5} = \frac{-20}{3 \times (-20)} \quad \therefore \quad h_2 = \frac{+5}{3} = \mathbf{+1.67\ cm}$$

Positive sign of h_2 shows that image is erect.

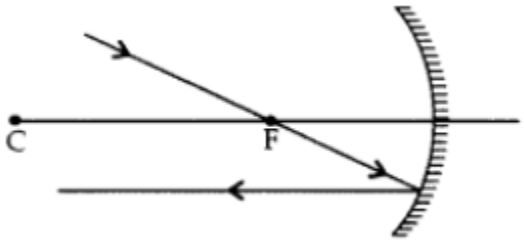
Thus a virtual, erect, diminished image is formed at a distance of 6.67 cm away from the lens on the same side of the object.

Question 33.
Draw the following diagram, in which a ray of light is incident on a concave/convex mirror, on your answer sheet. Show the path of this ray, after reflection, in each case. (2016 D)

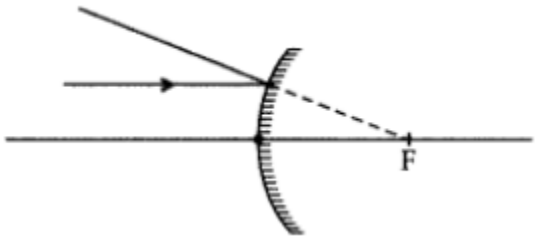


(i) (ii) (iii)

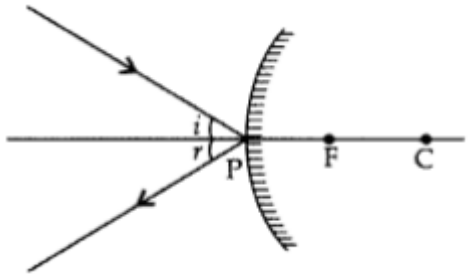
Answer:
(i)



(ii)



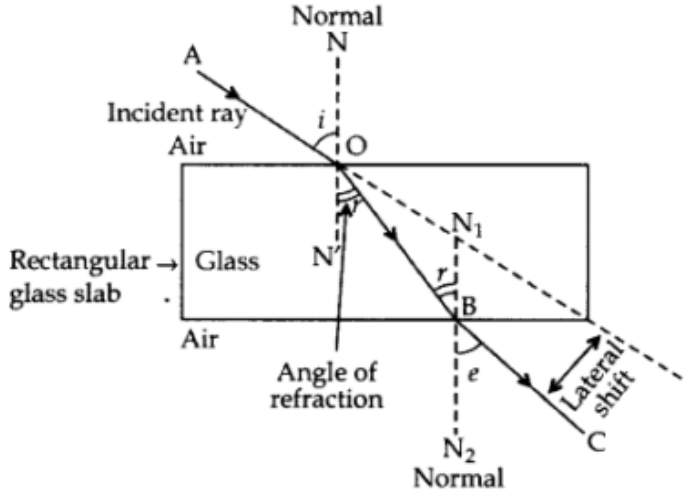
(iii)



Question 34.
(a) Draw a ray diagram to show the refraction of light through a glass slab and mark

angle of refraction and the lateral shift suffered by the ray of light while passing through the slab.
(b) If the refractive index of glass for light going from air to glass is 3/2, find the refractive index of air for light going from glass to air. (2016 D)

Answer:
(a) Ray diagram of refraction through a glass slab.



(b) Refractive index of glass from air: ${}_{a}n_{g} = 32$
Refractive index of air from glass: ${}_{g}n_{a} = 1a_{n}g$
$\Rightarrow 13/2=23$

Question 35.
The image of an object formed by a mirror is real, inverted and is of magnification -1. If the image is at a distance of 40 cm from the mirror, where is the object placed? Where would the image be if the object is moved 20 cm towards the mirror? State reason and also draw ray diagram for the new position of the object to justify your answer. (2016 OD)
Answer:
Magnification, m = -1; Image is real and inverted;
Image distance = -40 cm (∵ image is real)

$$\frac{-v}{u} = m \quad \Rightarrow \quad \frac{-(-40)}{u} = -1$$

$$\Rightarrow u = \frac{-(-40)}{-1} \quad \Rightarrow \quad u = -40 \text{ cm}$$

∴ Object is placed at 40 cm in front of the mirror.
When object distance is equal to the image distance and image is real, then the object is placed at C.
If the object is moved 20 cm towards the mirror, then its new position would be at the focus of the mirror.

According to the mirror formula:

$$\frac{1}{f}=\frac{1}{v}+\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{-40}+\frac{1}{-40}$$

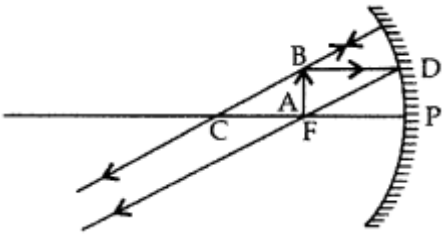
$$\frac{1}{f}=\frac{-1}{40}-\frac{1}{40} \quad \Rightarrow \quad \frac{1}{f}=\frac{-2}{40}=\frac{-1}{20}$$

Second case: f = -20 cm; u = -20 cm; v = ?

$$\frac{1}{v}+\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad \frac{1}{v}+\frac{1}{-20}=\frac{1}{-20}$$

$$\frac{1}{v}-\frac{1}{20}=\frac{-1}{20} \quad \Rightarrow \quad \frac{1}{v}=\frac{-1}{20}+\frac{1}{20}$$

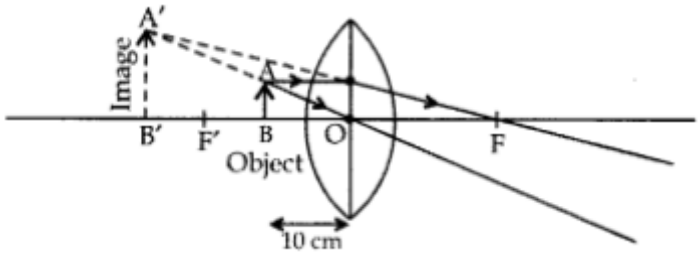
$$\frac{1}{v}=0 \Rightarrow v=\frac{1}{0}=\infty$$



Thus, image will be formed at infinity.

Question 36.
The image of an object formed by a lens is of magnification -1. If the distance between the object and its image is 60 cm, what is the focal length of the lens? If the object is moved 20 cm towards the lens, where would the image be formed? State reason and also draw a ray diagram in support of your answer. (2016 OD)

Answer:
Image with magnification -1 means
image is inverted.
image is of same size as the object.
image distance is equal to the object distance.
∴ The object is at 2f and image is at '2f' if distance between the object and its image is 60 cm.
∴ 4f = 60 cm
⇒ 2f = 602 = 30 cm
∴ f = 15 cm



It is a convex lens as magnification -1 is possible in convex lens only.
If the object is moved 20 cm towards the lens, the new object distance = 30 cm – 20 cm = 10 cm.
This distance is less than focal length, thus the image formed in this case would be virtual, erect, magnified and will be formed on the same side as the object.

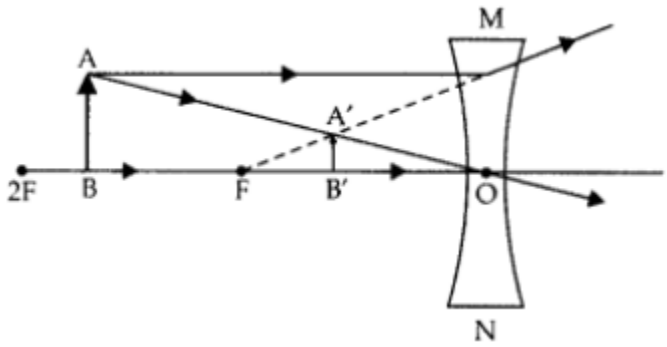
Question 37.
The image formed by a spherical mirror is real, inverted and is of magnification -2. If the image is at a distance of 30 cm from the mirror, where is the object placed? Find the focal length of the mirror. List two characteristics of the image formed if the object is moved 10 cm towards the mirror. (2016 OD)
Answer:
Nature of image formed by spherical mirror Real, inverted
Magnification, m = -2, Object distance, u = ?
Image distance, v = -30 cm (-ve sign is for real image) f = ?
$m = -\frac{v}{u}$
$\Rightarrow -\frac{v}{u} = -2$
$\Rightarrow -\frac{30}{u} = 2$
$2u = -30$
$\therefore u = -15$ cm
According to the mirror formula: $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$

$$\frac{1}{f} = \frac{1}{-30} + \frac{1}{-15} \Rightarrow \frac{1}{f} = \frac{-1}{30} - \frac{1}{15} = \frac{-1-2}{30} = \frac{-3}{30}$$

$$\frac{1}{f} = \frac{-1}{10} \therefore f = -10 \text{ cm}$$

If the object is shifted 10 cm towards the mirror then, u = 15 – 10 = 5 cm.
In this case the object is placed between pole and focus of the spherical mirror.
Therefore, the image formed is virtual, erect, magnified and behind the mirror.

Question 38.
If the image formed by a lens for all positions of an object placed in front of it is always erect and diminished, what is the nature of this lens? Draw a ray diagram to justify your answer. If the numerical value of the power of this lens is 10 D, what is its focal length in the Cartesian system? (2017 OD)
Answer:
This lens is a concave lens.



P = -10D (As lens is concave), f ?, P = $1f$
So,f = $1p$ ⇒ $1−10$0.1 m or -10 cm.
So, the focal length of the lens is 10 cm.

Long Answer Type

Question 1.
(a) If the image formed by a lens is diminished in size and erect,for all positions of the object, what type of lens is it?
(b) Name the point on the lens through which a ray of light passes undeviated.
(c) An object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from the lens is 30 cm. Find (i) the position (ii) the magnification and (iii) the nature of the image formed. (2011 D)
Answer:
(a) The lens is concave.
(b) Optical centre is the point on the lens through which a ray of light passes undeviated.
(c) Convex lens: Focal length, f = +20 cm,
Object distance, u = -30 cm
Image distance, v = ?,
Magnification, m = ?
Nature of the image = ?

According to lens formula:

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \quad \Rightarrow \quad \frac{1}{v}-\frac{1}{-30}=\frac{1}{20} \quad \Rightarrow \quad \frac{1}{v}+\frac{1}{30}=\frac{1}{20}$$

$$\Rightarrow \frac{1}{v}=\frac{1}{20}-\frac{1}{30}=\frac{3-2}{60}=\frac{1}{60} \quad \Rightarrow \quad v=+60\ \text{cm} \quad \therefore \quad m=\frac{v}{u}=\frac{60}{-30}=-2$$

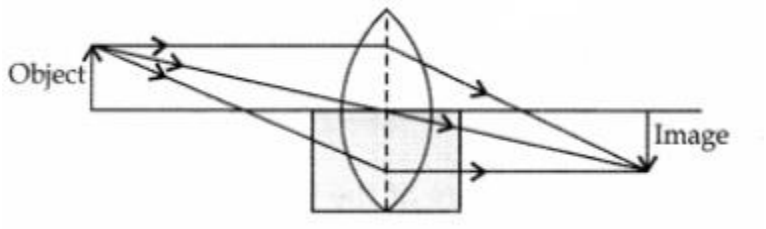
Nature: The +ve sign of v shows that the image is formed on the right side of the convex lens, so the image formed is real.

- The magnification is two (i.e., more than one) so the image is larger than the object.

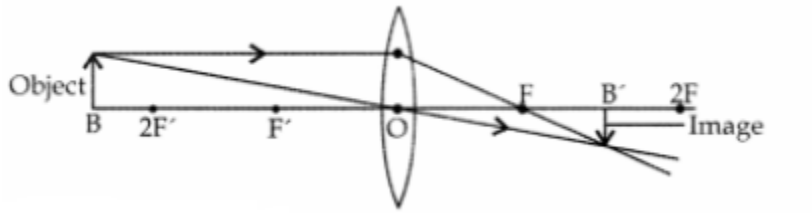
- The -ve sign for m shows that the image is formed below the principal axis. Hence the image is inverted.

∴ Nature of image: Real, inverted and magnified

Question 2.
(a) One-half of a convex lens is covered with a black paper. Will such a lens produce an image of the complete object? Support your answer with a ray diagram.
(b) An object 5 cm high is held 25 cm away from a converging lens of focal length 10 cm.
(i) Draw the ray diagram and
(ii) Calculate the position and size of the image formed.
(iii) What is the nature of the image?
Answer:
As we can see in the figure given, when the lower half of the convex lens is covered with a black paper, it still forms the complete image of the object as that formed with uncovered lens.
However the intensity of the image is reduced when the convex lens is covered with black paper.



(b) (i)



Converging lens (Convex lens): Height of the object, h_1 = 5 cm; object distance u = -25 cm;
Focal length, f = +10 cm

(ii) Image distance, v = ?, Image size, h_2 = ?
According to lens formula:

$$\frac{1}{v}-\frac{1}{u}=\frac{1}{f} \Rightarrow \frac{1}{v}-\frac{1}{-25}=\frac{1}{10} \Rightarrow \frac{1}{v}+\frac{1}{25}=\frac{1}{10}$$

$$\frac{1}{v}=\frac{1}{10}-\frac{1}{25} \Rightarrow \frac{1}{v}=\frac{5-2}{50}=\frac{3}{50} \Rightarrow v=\frac{50}{3}=+16.6\ \text{cm}$$

$$\frac{h_2}{h_1}=\frac{v}{u} \Rightarrow \frac{h_2}{5}=\frac{50}{3\times -25} \therefore h_2=\frac{-50^{2}\times 5}{3\times 25}=\frac{-10}{3}=-3.3\ \text{cm}$$

(iii) Nature of the image:

- The +ve sign of v shows that image is real.
- The -ve sign of h_2 shows that image is inverted.

∴ Size of image = 3.3 cm

Question 3.
(a) What is meant by 'power of a lens'?
(b) State and define the S.I. unit of power of a lens.
(c) A convex lens of focal length 25 cm and a concave lens of focal length 10 cm are placed in close contact with each other. Calculate the lens power of this combination. (2011 OD)
Answer:
(a) The power of a lens is a measure of the degree of convergence or divergence of light rays falling on it.
(b) The SI unit of the power of a lens is dioptre. One dioptre is the power of a lens whose focal length is 1 metre.
(c) Focal length of the convex lens:
f_1 = +25 cm = $+\frac{25}{100}$ m = +0.25 m
Focal length of the concave lens:
f_2 = -10 cm = $-\frac{10}{100}$ m = -0.10 m
$P_1 = 1/f_1 = \frac{1}{0.25}$ = +4D
$P_2 = 1/f_2 = \frac{1}{-0.10}$ = -10D
Power of combination, P = P_1 + P_2 = 4 + (-10) = -6D (dipole)
Question 4.
(a) Draw a ray diagram to show the formation of image of an object placed between infinity and the optical centre of a concave lens.
(b) A concave lens of focal length 15 cm forms an image 10 cm from the lens. Calculate
(i) the distance of the object from the lens
(ii) the magnification for the image formed
(iii) the nature of the image formed (2011 OD)

Answer:

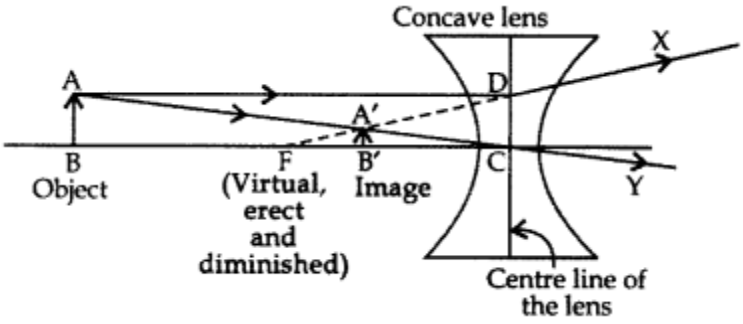
(a) When an object is placed any-where between infinity and optical centre of a concave lens, the image formed is

(i) between O and F.

(ii) virtual.

(iii) erect.

(iv) diminished.



(b) Concave lens.

Focal length, f = -15 cm,

v = -10 cm,

u = ?, m = ?

Nature of the image = ?

According to lens formula:

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \Rightarrow \quad \frac{1}{u} = \frac{1}{v} - \frac{1}{f} \quad \Rightarrow \quad \frac{1}{u} = \frac{1}{-10} - \frac{1}{(-15)}$$

$$\Rightarrow \frac{1}{u} = \frac{-1}{10} + \frac{1}{15} = \frac{-3+2}{30} = \frac{-1}{30} \quad \therefore \quad u = -30 \text{ cm}$$

(i) The distance of the object from the lens = 30 cm

(ii) Magnification, m = $vu = -10 - 30 = 13$

(iii) Nature: +ve sign of m shows that the image is erect.

Since the value of m is less than (1), therefore image is diminished.

Question 5.

State the law of refraction of light that defines the refractive index of a medium with respect to the other. Express it mathematically. How is refractive index of any medium 'A' with respect to a medium 'B' related to the speed of propagation of light in two media A and B? State the name of this constant when one medium is vacuum or air.

The refractive indices of glass and water with respect to vacuum are 3/2 and 4/3 respectively. If the speed of light in glass is 2×10^8 m/s, find the speed of light in (i) vacuum, (ii) water. (2012 D)

Answer:

The second law of refraction gives a relationship between the angle of incidence and

the angle of refraction. This law is also known as Snell's Law of Refraction.
According to the Snell's law, "The ratio of sine of angle of incident to the sine of refraction is constant for a given pair of media."
sini/sinr = constant. This constant is called refractive index.
Example: A ray of light travelling in air enters into glass and gets refracted
then, sini/sinr = n
where [sin i = sine of angle of incidence in air
sin r = sine of angle of refraction in glass
n = refractive index of glass]
The refractive index of medium 'A' with respect to medium 'B' is equal to the ratio of speed of light in medium 'A' to the speed of light in medium 'B'.

$$_{B}n_{A} = \frac{\text{Speed of light in medium B}}{\text{Speed of light in medium A}}$$

$$_{B}n_{A} = \frac{v_B}{v_A}$$

where [$_{B}n_{A}$ = refractive index of A w.r.t. B
v_B = velocity of light in medium B
V_A = velocity of light in medium A]

When light is going from vacuum to another medium, then the value of refractive index is called the absolute refractive index.
$_{v}n_{g} = 32$, $_{v}n_{w} = 43$,
$v_g = 2 \times 10^8$ m/s, $u_v = ?$, $v_w = ?$

$$\text{Formula: } {}_{v}n_{g} = \frac{v_v}{v_g}$$

$$\therefore \quad \frac{3}{2} = \frac{v_v}{2\times 10^8} \quad \Rightarrow \quad v_v = \frac{3}{2} \times 2 \times 10^8 = 3 \times 10^8 \text{ m/s}$$

$\therefore$ Velocity of light in vacuum = 3×10^8 m/s

$$_{v}n_{w} = \frac{v_v}{v_w} \quad \Rightarrow \quad \frac{4}{3} = \frac{3\times 10^8}{v_w}$$

$$\Rightarrow \quad r_w = \frac{3 \times 100^{25} \times 10^6 \times 3}{4} = 225 \times 10^6 = 2.25 \times 10^8 \text{ m/s}$$

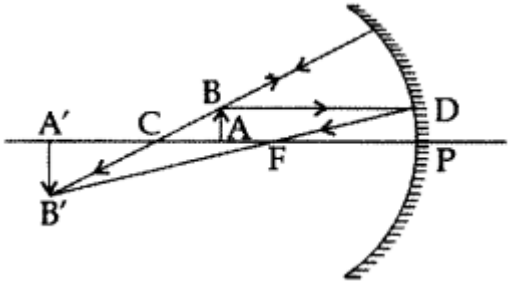
$\therefore$ Velocity of light in water = 2.25×10^8 m/s

Question 6.
List the sign conventions for reflection of light by spherical mirrors. Draw a diagram and apply these conventions in the determination of focal length of a spherical mirror which forms a three times magnified real image of an object placed 16 cm in front of it. (2012 D)
Answer:
Sign conventions for reflection of light by spherical mirrors:
(i) All the distances are measured from pole of the mirror as origin.

(ii) The object is always placed to the left of the mirror.
(iiii) Distances measured in the direction of incident light are considered to be positive (+ve).
(iv) Distances measured against the direction of incident light are considered to be negative (-ve).
(v) The perpendicular distances to the principal axis in the upward direction are considered to be positive (+ve).
(vi) The perpendicular distances to the principal axis in the downward direction are considered to be negative (-ve).
u = object distance, v = image distance, f = focal length
h = height of the object, h'= height of the image
P = Principal axis, C = Centre of curvature, F = Focus

Type of mirror	Position of object	u	v	f	h	h'
Concave	Between P & F	-ve	+ve	-ve	+ve	+ve
Concave	between F & C	-ve	-ve	-ve	+ve	-ve
Concave	at C	-ve	-ve	-ve	+ve	-ve
Concave	beyond C	-ve	-ve	-ve	+ve	-ve
Convex	in front of it	-ve	+ve	+ve	+ve	+ve

Diagram: When the object is between F and C (centre of curvature):



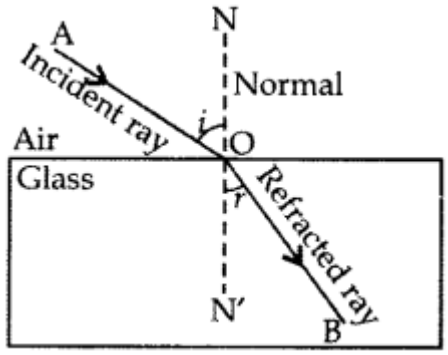
The image formed is
(i) real,
(ii) inverted,
(iii) magnified, and
(iv) beyond C.

PA = Object distance = This distance lies in the direction opposite to the incident ray
∴ PA, i.e., u = -16
Magnification is 3 times
∴ m = -3 cm
$-vu = m \Rightarrow -v-16 = -3$
∴ -v = 3 × 16 = 48 ⇒ v = -48 cm
According to mirror formula:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{-16} + \frac{1}{-48} \quad \Rightarrow \quad \frac{1}{f} = \frac{-1}{16} - \frac{1}{48} = \frac{-3-1}{48} = \frac{-4^{1}}{48_{12}} = -\frac{1}{12}$$

The negative (-) sign of focal length shows that it is a concave lens of focal length 12 cm.
Thus an inverted, magnified image is formed on the screen.

Question 7.
With the help of a ray diagram, state what is meant by refraction of light. State Snell's law for refraction of light and also express it mathematically. (2012 OD)
The refractive index of air with respect to glass is 2/3 and the refractive index of water with respect to air is 4/3. If the speed of light in glass is 2×10^8 m/s, find the speed of light in (a) air, (b) water.
Answer:
Refraction of light. The bending of light when it passes from one medium to another is called refraction of light.
Diagram and Snell's law. The second law of refraction of light is the Snell's Law of Refraction. It states that the ratio of sine of the angle of incidence to the sine of angle of refraction is a constant for a given pair of medium.
$\sin i/\sin r$ = constant (n)
This constant (n) is called refractive index of the medium.



(a) Refractive index of air with respect to glass:

$$g^{n}a = \frac{\text{Velocity of light in glass}}{\text{Velocity of light in air}} \Rightarrow g^{n}a = \frac{v_g}{v_a} = \frac{2}{3}$$

$\because v_g = 2 \times 10^8$ m/s

$v_a = ?$ $\therefore \frac{2 \times 10^8}{v_a} = \frac{2}{3}$

$\Rightarrow \frac{3 \times 2 \times 10^8}{2} = v_a$ $\therefore v_a = 3 \times 10^8$ m/s

∴ Velocity of light in air = 3 × 108 m/s

(b) Refractive index of water with respect to air:

$$_a n_w = \frac{v_a}{v_w} = \frac{4}{3} \quad \because v_a = 3 \times 10^8 \text{ m/s} \quad \text{...[From (a)}$$

$\Rightarrow \frac{3 \times 10^8}{v_w} = \frac{4}{3}$ $\Rightarrow \frac{3 \times 3 \times 10^8}{4} = v_w$

$\Rightarrow v_w = \frac{9}{4} \times 10^8$ $\therefore v_w = 2.25 \times 10^8$ m/s

∴ Velocity of light in water = 2.25×10^8 m/s

Question 8.
List the new Cartesian sign convention for reflection of light by spherical mirrors. Apply these conventions for calculating the focal length and nature of a spherical mirror which forms a 1/3 times magnified virtual image of an object placed 18 cm in front of it. (2012 OD)

Answer:
New Cartesian Sign Conventions for spherical mirrors.
f = ?,
Nature of spherical mirror = ?
∵ The image is 13 times magnifide and virtual
∴ magnification, m = +13 [+ve sign of m is for virtual image]
u = -18 cm

$$\frac{-v}{u} = m \quad \Rightarrow \quad \frac{\cancel{-}v}{\cancel{-}18} = \frac{1}{3} \quad \Rightarrow \quad v = \frac{1}{\cancel{3}} \times \cancel{18}^{6} = +6$$

According to the mirror formula:

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u} \quad \Rightarrow \quad \frac{1}{f} = \frac{1}{6} + \frac{1}{-18} = \frac{1}{6} - \frac{1}{18} \quad \Rightarrow \quad \frac{1}{f} = \frac{3-1}{18} = \frac{2}{18} = \frac{1}{9}$$

∴ f = +9 cm
Positive (+ve) sign of f shows that the spherical mirror is convex having focal length of 9 cm.

Question 9.
(a) State the laws of refraction of light. Give an expression to relate the absolute refractive index of a medium with speed of light in vacuum.
(b) The refractive indices of water and glass with respect to air are 4/3 and 3/2 respectively. If the speed of light in glass is 2×10^8 ms^{-1}, find the speed of light in (i) air, (ii) water. (2014 OD)

Answer:
(a) There are two laws of refraction of light:
(i) The first law of refraction of light states that the incident ray, the refracted ray and the normal at the Point of incidence, all lie in the same plane.
(ii) The second law of refraction of light is the Snell's law of Refraction. It states that the ratio of sine of the angle of incidence to the sine of angle of refraction is a constant for a given pair of medium.
sini/sinr = constant(n)
This constant (n) is called refractive index of the medium.

$$\text{Absolute refractive index of a medium} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

(b) ${}_aN_w = 43$, ${}_aN_g = 32$
Speed of light in glass, $V_g = 2 \times 10^8$ m/s
Speed of light in air, V_a = ?
Speed of light in water, v_w = ?

$${}_aN_w = \frac{v_a}{v_w} \quad \Rightarrow \quad \frac{4}{3} = \frac{v_a}{v_w}$$

$${}_aN_g = \frac{v_a}{v_g} \quad \Rightarrow \quad \frac{3}{2} = \frac{v_a}{2 \times 10^8}$$

$$\Rightarrow \quad v_a = \frac{3}{\cancel{2}} \times \cancel{2} \times 10^8 = \mathbf{3 \times 10^8\ m/s}$$

putting the value of v_a in equation (i),

$$\frac{4}{3} = \frac{3 \times 10^8}{v_w} \quad \Rightarrow \quad v_w = 3 \times 10^8 \times \frac{3}{4} = \frac{9}{4} \times 10^8 = \mathbf{2.25 \times 10^8\ m/s}$$

Question 10.
State Snell's law of refraction of light. Write an expression to relate refractive index of a medium with speed of light in vacuum.
The refractive index of a medium 'a' with respect to medium 'b' is 2/3 and the refractive index of medium 'b' with respect to medium 'c' is 4/3. Find the refractive index of medium 'c' with respect to medium 'a'. (2013 D)

Answer:
Snell's law states that, "the ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of media".
sinisinr = Constant
The value of constant for a ray of light passing from air into a particular medium is called the refractive index of the medium.

$$\text{Refractive index (of a medium)} = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$$

Refractive index of medium 'a' with respect to 'b' = ${}_bn_a$ = 23

$${}_bn_a = \frac{\text{Speed of light in medium 'b'}}{\text{Speed of light in medium 'a'}} = \frac{v_b}{v_a} = \frac{2}{3}$$

Refractive index of medium 'b' with respect to 'c' = ${}_cn_b$ = 43

$${}_cn_b = \frac{\text{Speed of light in medium 'c'}}{\text{Speed of light in medium 'b'}} = \frac{v_c}{v_b} = \frac{4}{3}$$

Refractive index of medium 'c' with respect to 'a' = ${}_an_c$ = ?

$${}_an_c = \frac{\text{Speed of light in medium 'a'}}{\text{Speed of light in medium 'c'}} = \frac{v_a}{v_c} = ?$$

$$\because \quad \frac{v_b}{v_a} = \frac{2}{3} \qquad \Rightarrow \qquad v_a = \frac{3}{2}v_b$$

$$\because \quad \frac{v_c}{v_b} = \frac{4}{3} \qquad \Rightarrow \qquad v_c = \frac{4}{3}v_b$$

$${}_an_c = \frac{v_a}{v_c} = \frac{\frac{3}{2}v_b}{\frac{4}{3}v_b} = \frac{3}{2} \times \frac{3}{4} = \frac{9}{8}$$

Question 11.
Define the term absolute refractive index. The absolute refractive index of diamond is 2.42. What is the meaning of this statement? Refractive indices of media A, B, C and D are given below: (2013 D)

Media	Refractive index

A	1.33
B	1.44
C	1.52
D	1.65

In which of these four media is the speed of light (i) minimum and (ii) maximum?
Find the refractive index of medium C with respect to medium B.

Answer:

When light is going from vacuum to another medium, then the value of refractive index is called absolute refractive index to the medium.
The absolute refractive index of diamond is 2.42. It means that the speed of light in diamond is 12.42 times the speed of light in vacuum.
As the refractive indices increase, speed of the light decreases in the medium.
(i) The refractive index of medium D is maximum (1.65). So the speed of light in medium D is minimum.
(ii) The refractive index of medium A is minimum (1.33). So the speed of light in medium A is maximum.

bnc = ? [Refractive index of medium C with respect to medium B]

$$n_B = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium B}}$$

$$1.44 = \frac{v}{v_B} \quad \Rightarrow \quad v_B = \frac{v}{1.44}$$

$$n_C = \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium C}}$$

$$1.52 = \frac{v}{v_C} \quad \Rightarrow \quad v_C = \frac{v}{1.52}$$

$${}_Bn_C = \frac{\text{Speed of light in medium B}}{\text{Speed of light in medium C}}$$

$${}_Bn_C = \frac{v_B}{v_C} \quad \Rightarrow \quad {}_Bn_C = \frac{\frac{v}{1.44}}{\frac{v}{1.52}} \quad \text{...[From (i) an}$$

$${}_Bn_C = \frac{\cancel{v}}{1.44} \times \frac{1.52}{\cancel{v}} = \frac{\cancel{152}^{76}}{\cancel{144}_{72}} = \frac{\cancel{76}^{\cancel{38}^{19}}}{\cancel{72}_{\cancel{36}_{18}}} = 1.055 = \mathbf{1.06}$$

Question 12.

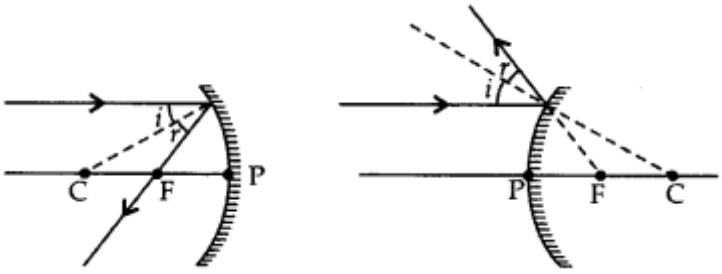
(a) To construct a ray diagram we use two light rays which are so chosen that it is easy to know their directions after reflection from the mirror. List these two rays and state the path of these rays after reflection. Use these two rays to locate the image of an object placed between infinity and the centre of curvature of a concave mirror.

(b) Draw a ray diagram to show the formation of image of an object placed between the pole and principal focus of a concave mirror. How will the nature and size of the image formed change, if the mirror is replaced by a converging lens of same focal length? (2012 OD)

Answer:

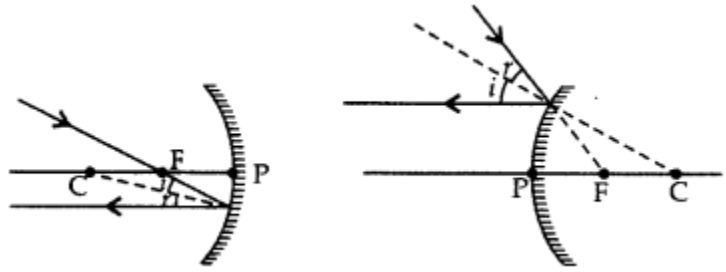
(a) The rays for obtaining image from the mirror after reflection are so chosen that it is easy to know their directions after reflection from the mirror.

(i) A ray parallel to the Principal axis, after reflection Passes through the focus in concave
mirror or appears to pass through the focus in convex mirror.

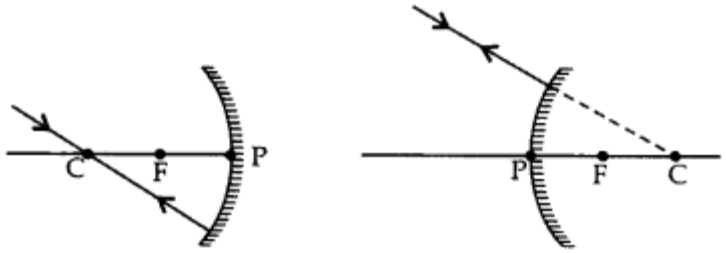


(ii) A ray passing through the principal focus of a concave mirror or directed towards the principal focus in convex mirror after reflection will emerge parallel to the

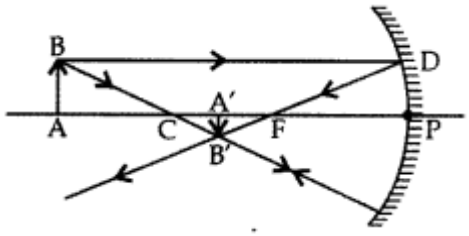
principal axis.



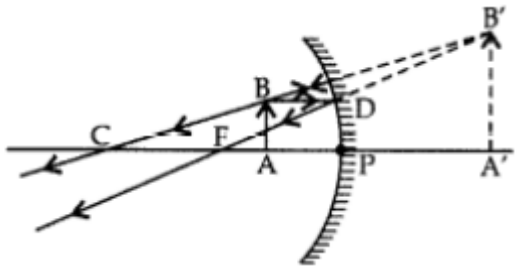
(iii) A ray passing through the centre of curvature of the concave mirror or directed in the direction of the centre of curvature of the convex mirror is reflected back along the same Path after reflection.



when the object is placed between infinity and the centre of curvature of a concave mirror.

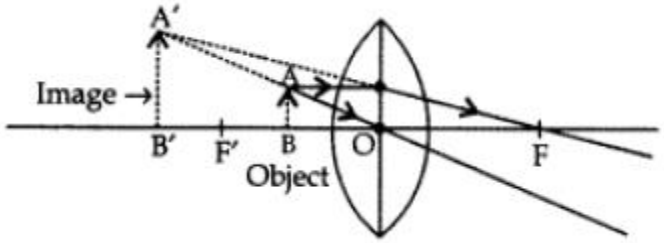


(b) when the object is Placed between the pole and principal focus of a concave mirror.



If the object is placed between the optical centre and principal focus of a converging

lens (convex lens).



Question 13.
List the sign conventions that are followed in case of refraction of light through spherical lenses. Draw a diagram and apply these conventions in determining the nature and focal length of a spherical lens which forms a four times magnified real image of an object placed 20 cm from the lens. (2013 OD)

Answer:
Sign conventions in case of refraction of light through spherical lenses:

- All the distances are measured from the optical centre of the lens.
- The distances measured in the same direction as that of incident light are taken as positive (+ve).
- The distances measured in the opposite direction as that of incident light are taken as negative (-ve).
- The perpendicular distances to the principal axis in the upward direction are taken as positive (+ve).
- The perpendicular distances to the principal axis in the downward direction are taken as negative (-ve).
  u = object distance from O (optical centre), v = image distance from O, f = focal length

These rules conclude that:

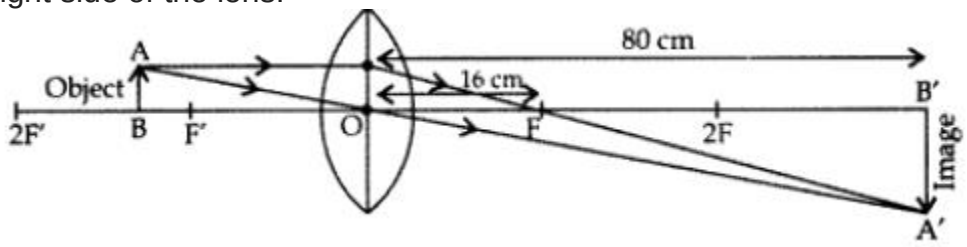
- V (object distance) is always -ve
- 'f' of convex lens is always +ve
- 'f' of concave lens is always -ve
- 'v' in case of virtual image is always -ve
- V in case of real image is always +ve.
- Real image is always inverted thus h_2 (size of the image) in case of real image is always -ve.
- h_2 (size of the image) in case of virtual image is always +ve as it is always erect.

Nature of the image = ?, Focal length of the lens = ?
$h_2 = -4h_1$ …(Real image is always formed in downward direction)
m = +4 …(+ve sign for real image, as the image will be formed on the right side of the lens)

u = -20 …(-ve sign shows the object is placed on the left side of the lens)

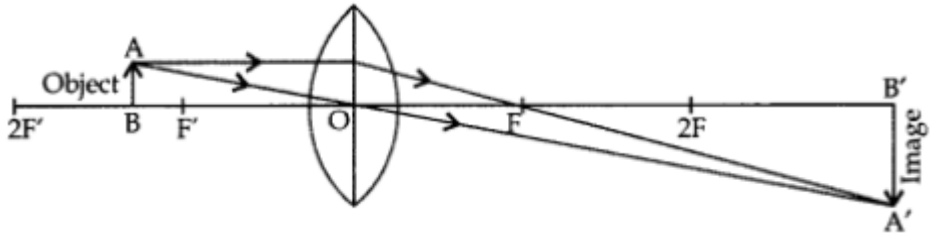
$$m = \frac{h_2}{h_1} \qquad m = \frac{v}{u} \qquad \Rightarrow \qquad \frac{h_2}{h_1} = \frac{v}{u} \qquad \Rightarrow \qquad \frac{-4\,h_1}{h_1} = \frac{v}{-20}$$

∴ v = -4 × -20 = +80 cm
∴ Image is formed 80 cm from the lens on the opposite side of the object, i.e., on the right side of the lens.



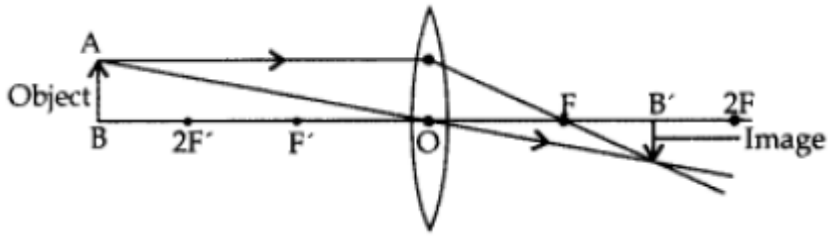
Question 14.
A student wants to project the image of a candle flame on the walls of school laboratory by using a lens:
(a) Which type of lens should he use and why?
(b) At what distance in terms of focal length 'F' of the lens should he place the candle flame so as to get (i) a magnified, and (ii) a diminished image respectively on the wall?
(c) Draw ray diagram to show the formation of the image in each case. (2014 D)
Answer:
(a) A convex lens should be used. This is because it can produce a real image of the candle flame on the wall as it is a converging lens where refracted rays actually meet.

(b) & (c) (i) A real magnified image is formed when the candle flame is placed between F and 2F from the convex lens on the other side of the wall.

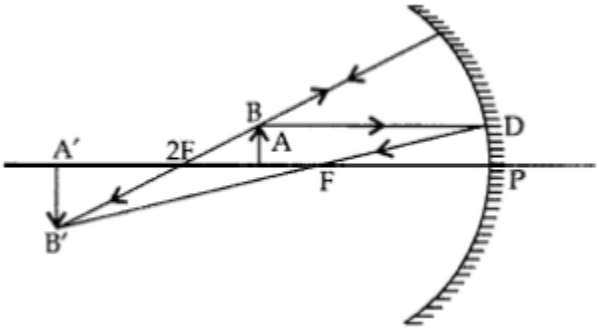


(ii) A real diminished image is formed when the candle flame is placed beyond 2F

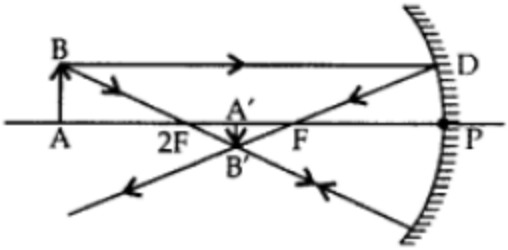
from the convex lens on the other side of the wall.



Question 15.
A student wants to project the image of a candle flame on the walls of school laboratory by using a mirror. (2014 D)
(a) Which type of mirror should he use and why?
(b) At what distance in terms of focal length 'F' of the mirror should he place the candle flame so as to get the magnified image on the wall?
(c) Draw a ray diagram to show the formation of image in this case.
(d) Can he use this mirror to project a diminished image of the candle flame on the same wall? State 'how' if your answer is 'yes' and 'why not' if your answer is 'no'.
Answer:
(a) Concave mirror should be used as only this mirror will produce a real image (i.e., on the wall).
(b) The object should be placed between 'F' and '2F' so as to get the magnified image on the wall.
(c)



(d) When the candle flame is placed beyond 2F, A diminished real image will be formed on the wall.



Question 16.
(a) Explain the following terms related to spherical lenses:
(i) optical center
(ii) centres of curvature
(iii) principal axis
(iv) aperture
(v) principal focus
(vi) focal length
(b) A converging lens has focal length of 12 cm. Calculate at what distance should the object be placed from the lens so that it forms an image at 48 cm on the other side of the lens. (2014 OD)

Answer:
(a) (i) Optical center. It is a point within the lens that lies on the principal axis through which a ray of light passes undeflected.
(ii) Centre of curvature. The centre of curvature of the surface of a lens is the centre of the sphere of which it forms a part. A lens has two centres of curvature because it has two surfaces.
(iii) Principal axis. It is a line through the centres of curvatures of the lens.
(iv) Aperture. The diameter of the circular boundary of the lens is called the aperture of the lens.
(v) Principal focus. A beam of light parallel to the principal axis either converges to a point or appears to diverge from a point on the principal axis after refraction through the lens, is called the principal focus. All lenses have two principal focuses.
(vi) Focal length. The distance between the optical centre and the principal focus of the lens is called its focal length.

(b) A converging lens is a convex lens.
f = +12 cm; u = ?; v = +48 cm (+ve as it is formed on other side of the object)
According to lens formula:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{12}=\frac{1}{48}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{u}=\frac{1}{48}-\frac{1}{12}=\frac{1-4}{48}=\frac{-3}{48}=\frac{1}{16}$$

∴ u = -16 cm

Question 17.
(a) State the laws of refraction of light. Explain the term absolute refractive index of a medium and write an expression to relate it with the speed of light in vacuum. (2015 D)
(b) The absolute refractive indices of two media 'A' and 'B' are 2.0 and 1.5 respectively. If the speed of light in medium 'B' is 2×10^8 m/s, calculate the speed of light in: (i) vacuum, (ii) medium 'A'.

Answer:
(a) Laws of Refraction:
(i) The first law of refraction of light states that the incident ray, the refracted ray and the normal at the point of incidence, all lie in the same plane.

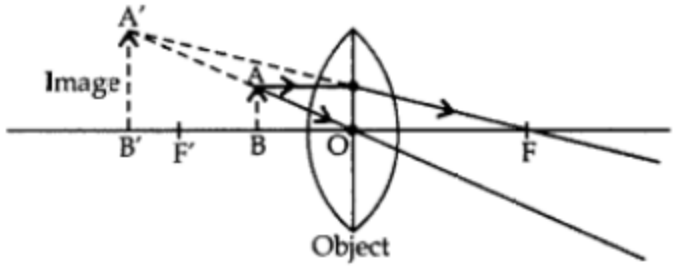
(ii) The second law of refraction of light is the Snell's Law of Refraction. It states that the ratio of sine of the angle of incidence to the sine of angle of refraction is a constant for a given pair of medium.
$\frac{\sin i}{\sin r}$ = constant (n)
This constant (n) is called refractive index of the medium.

- When the light is going from vacuum to another medium, then the value of refractive index is called the absolute refractive index.
- The ratio of speed of light in vacuum to the speed of light in a medium is called the absolute refractive index of that medium, i.e.,

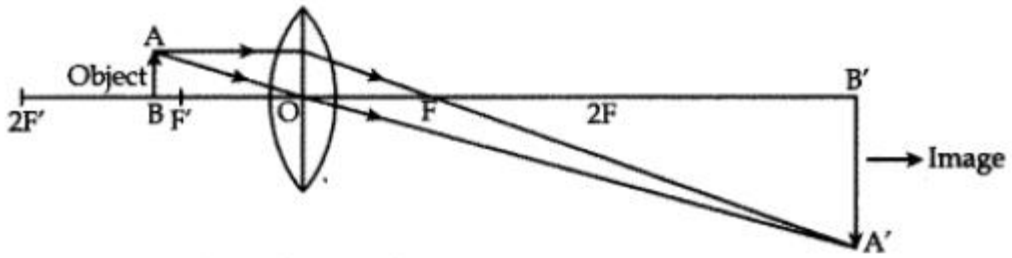
$$\text{Absolute refractive index (of a medium)} = \frac{\text{Speed of light in vacuum } (c)}{\text{Speed of light in medium } (v)}$$

(b) $n_A = 2.0$; $n_B = 1.5$; $v_B = 2 \times 10^8$ m/s
(i) Speed of light in vacuum, c = ?
$n_B = 1.5 = \frac{c}{v_B}$
$\therefore c = n_B v_B = 1.5 \times 2 \times 10^8$ m/s $= 3 \times 10^8$ m/s
(ii) For medium 'A': $n_A = \frac{c}{v_A}$
$\therefore v_A = \frac{c}{v_A} = \frac{3 \times 10^8 \text{m/s}^2}{} = 1.5 \times 10^8$ m/s

Question 18.
"A convex lens can form a magnified erect as well as magnified inverted image of an object placed in front of it." Draw ray diagram to justify this statement stating the position of the object with respect to the lens in each case.
An object of height 4 cm is placed at a distance of 20 cm from a concave lens of focal length 10 cm. Use lens formula to determine the position of the image formed. (2015 D)
Answer:
A convex lens can form a magnified erect image when the object is placed between the optical centre and principal focus of the convex lens (i.e., between O and F').



A convex lens can form a magnified inverted image when the object is placed between focus and the centre of curvature (i.e., between F' and 2F').



Object height, h = 4 cm;
Object distance, u = -20 cm
Nature of the lens = concave lens;
Focal length = f = -10 cm
Image distance, v = ?
According to the lens formula,

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{v}=\frac{1}{f}+\frac{1}{u} \quad \Rightarrow \quad \frac{1}{v}=\frac{1}{-10}+\frac{1}{-20}=\frac{-2-1}{20}=\frac{-3}{20}$$

∴ v = -6.66 cm
The image is formed at a distance of 6.66 cm in front of the concave lens.

Question 19.
The image of a candle flame placed at a distance of 30 cm from a spherical lens is formed on a screen placed on the other side of the lens at a distance of 60 cm from the optical centre of the lens. Identify the type of lens and calculate its focal length. If the height of the flame is 3 cm, find the height of its image. (2015 D)
Answer:
Since the image is formed on the screen, the image is real. A concave lens cannot form a real image. Therefore, the lens is convex.
Object distance, u = -30 cm
Image distance, v = +60 cm
Focal length, f = ?
Height of the image, h_1 = +3
Nature of lens = ?
Height of the image, h_2 = ?
According to lens formula:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{+60}-\frac{1}{-30}=\frac{1}{60}+\frac{1}{30}=\frac{1+2}{60}=\frac{3}{60} \quad \therefore \quad f=+20\ \text{cm}$$

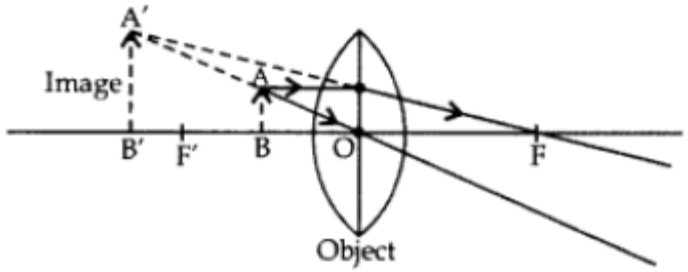
Magnification of convex lens, m = $\frac{v}{u}$

$$\frac{h_2}{h_1}=\frac{v}{u} \quad \Rightarrow \quad \frac{h_2}{+3}=\frac{+60}{-30} \quad \Rightarrow \quad h_2=\frac{+60}{-30}\times 3$$

Thus the image of the candle flame is 6 cm high and inverted (as indicated by the -ve sign).

Question 20.
What is meant by power of a lens? Define its S.I. unit.
You have two lenses A and B of focal lengths +10 cm and -10 cm respectively. State the nature and power of each lens. Which of the two lenses will form a virtual and magnified image of an object placed 8 cm from the lens? Draw a ray diagram to justify your answer. (2015 OD)

Answer:
The power of a lens is a measure of the degree of convergence or divergence of light rays falling on it. The SI unit of the power of a lens is dioptre. One dioptre is the power of a lens whose focal length is 1 metre.
Lens A: F_A = +10 cm = $+10100$ = 0.1 m
$P_A = 1F_A = 1+0.1$ = +10D
The power of a convex lens is positive therefore, lens A is a convex lens.
Lens B: F_B = -10 cm = -10100 = -0.1 m
$P_B = 1F_B = 1-0.1$
The power of a concave lens is negative therefore, lens B is a concave lens.
When an object is placed at 8 cm (i.e., between the optical centre and principal focus) only convex lens will form the virtual and magnified image.



Therefore, lens A will form a virtual and magnified image of the object placed 8 cm from it. When the object is placed between the optical centre and the focus: (i.e., between O and F') the image formed is behind the object (on the same side), virtual, erect and magnified.

Question 21.
One half of a convex lens of focal length 10 cm is covered with a black paper. Can such a lens produce an image of a complete object placed at a distance of 30 cm from the lens? Draw a ray diagram to justify your answer.
A 4 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 20 cm. The distance of the object from the lens is 15 cm. Find nature, position and size of the image. (2015 OD)

Answer:
(i) Yes. If a convex lens of focal length 10 cm is covered one half with a black paper, it can produce an image of the complete object between F_2 and $2F_2$. The rays of light coming from the object get refracted by the upper half of the lens.
The image formed will be real, inverted and diminished.

(ii) Object height, h_1 = 4 cm
Focal length f = +20 cm
Object distance, u = -15 cm
Image distance, v = ?
Image height h_2 = ?
By lens formula,

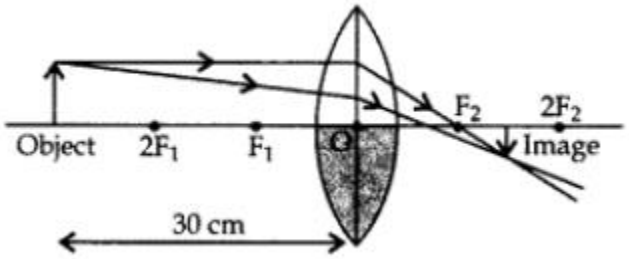
$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{v}=\frac{1}{f}+\frac{1}{u}=\frac{1}{+20}+\frac{1}{-15}=\frac{1}{20}-\frac{1}{15} \quad \Rightarrow \quad \frac{1}{v}=\frac{3-4}{60}=\frac{-1}{60}$$

∴ v = -60cm
Negative sign of v shows that the image is virtical.

$\frac{h_2}{h_1}=\frac{v}{u}$

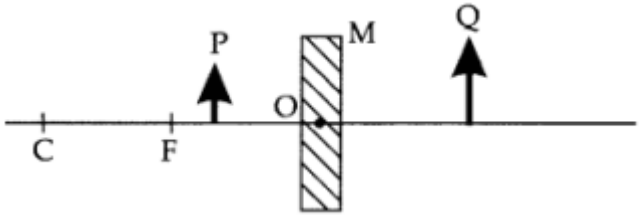
$\Rightarrow \frac{h_2}{+4}=\frac{-60}{-15}$

∴ $h_2 = \frac{-60}{-15} \times 4 = +16$ cm



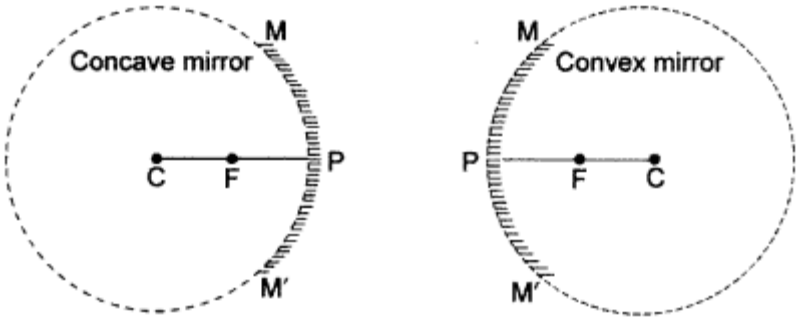
Negative sign of h_2 shows that the image is erect. Therefore, a virtual, erect, magnified (16 cm) image will be formed at a distance of 60 cm on the same side as of the object by the convex lens.

Question 22.
(a) Define the following terms in the context of spherical mirrors:
(i) Pole (ii) Centre of curvature (iii) Principal axis (iv) Principal focus
(b) Draw ray diagrams to show the principal focus of a:
(i) Concave mirror (ii) Convex mirror
(c) Consider the following diagram in which M is a mirror and P is an object and Q is its magnified image formed by the mirror. (2016 D)



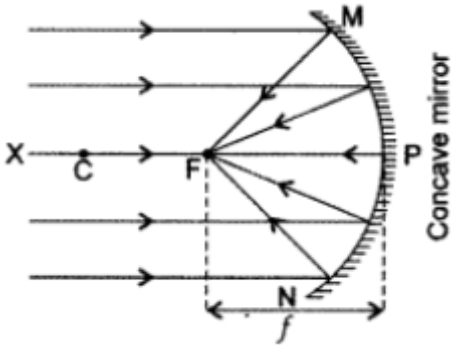
State the type of the mirror M and one characteristic property of the image Q.

Answer:
(a)



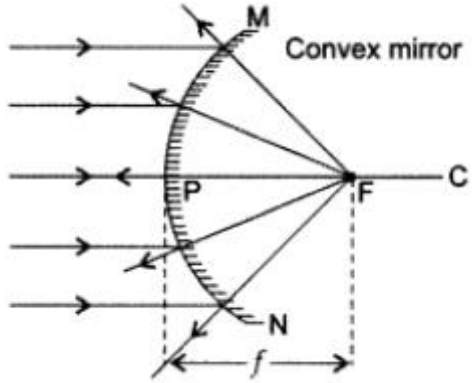
(i) Pole. The middle point of the reflecting surface of a spherical mirror is called pole. The letter P represents pole, MP = M'P.
(ii) Centre of curvature. It is the centre of the sphere of glass of which the mirror is a part. The letter C represents the centre of curvature.
(iii) Principal axis of a spherical mirror is the straight line joining the centre of curvature and pole of the mirror.
(iv) Principal focus. The mid-point of CP is called focus (F). It is the point on the principal axis of a spherical mirror where all incident rays parallel to the principal axis meet or appear to diverge after reflection.

(b) Ray diagrams of principal focus:
(i) Concave mirror: In a concave mirror the reflected rays of incident rays parallel to principal axis actually pass through the X focus (F). Thus concave mirror has a real principal focus.



(ii) Convex mirror. In a convex mirror the reflected rays do not actually pass through the focus (F). Thus, a convex mirror has a virtual principal focus situated behind the

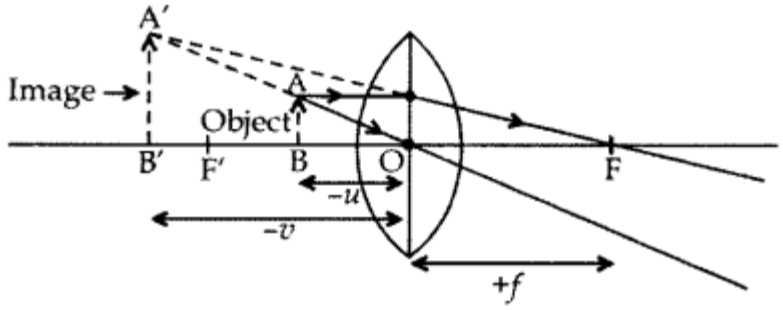
mirror.



(c) The mirror used in the given diagram is a concave spherical mirror. Image formed (Q) is virtual and magnified.

Question 23.
(a) Draw a ray diagram to show the formation of image by a convex lens when an object is placed in front of the lens between its optical centre and principal focus.
(b) In the above ray diagram mark the object-distance (u) and the image-distance (v) with their proper signs (+ve or -ve as per the new Cartesian sign convention) and state how these distances are related to the focal length (f) of the convex lens in this case.
(c) Find the power of a convex lens which forms a real, and inverted image of magnification -1 of an object placed at a distance of 20 cm from its optical centre.
(2016 D)

Answer:
(a) When the object is placed in front of a convex lens between its optical centre and principal focus (i.e., between O and F'):



The image formed is
(i) behind the object (on the same date),
(ii) virtual,
(iii) erect, and
(iv) magnified.

(b) -u (OB); -v (OB'); +f(OF)
The relation between u, v and / is given by the lens formula $1f=1v-1u$
As both (u) and (v) are negative, the above equation will change to

$$\frac{1}{f}=\frac{1}{(-v)}-\frac{1}{(-u)} \quad \Rightarrow \quad \frac{1}{f}=\frac{-1}{v}+\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{u}-\frac{1}{v}$$

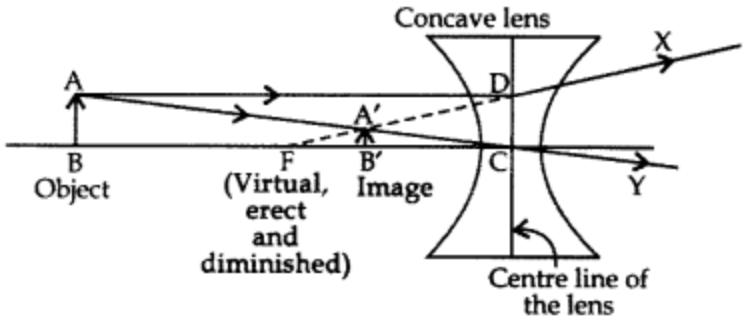
(c) Type of lens = Convex lens, Object distance, u = —20 cm
Magnification, m = —1, Nature of image = Real and inverted
∵ m = vu ⇒ -1 = $v-2$ ⇒ v = +20 cm
According to the lens formula:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{20}-\frac{1}{-20} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{20}+\frac{1}{20}$$

$$\Rightarrow \frac{1}{f}=\frac{2}{20} \quad \Rightarrow \quad f=+10 \text{ cm}=\frac{10}{100} \text{ m}=\frac{1}{10} \text{ m} \quad \therefore \quad \text{Power, } P=\frac{1}{f}=\frac{1}{1/10}$$

P = +10D

Question 24.
(a) Draw a ray diagram to show the formation of image by a concave lens when an object is placed in front of it.
(b) In the above diagram mark the object-distance (u) and the image-distance (v) with their proper signs (+ve or -ve as per the new Cartesian sign convention) and state how these distances are related to the focal length (f) of the concave lens in this case.
(c) Find the nature and power of a lens which forms a real and inverted image of magnification -1 at a distance of 40 cm from its optical centre. (2016 D)
Answer:
(a) Concave lens.



(b) CB = -u, CF = -f, CB' = -v
The relation between u, v and f is given by the lens formula:
$1f=1v-1u$
As both u and v are negative the above equation will change to

$$\frac{1}{f}=\frac{1}{(-v)}-\frac{1}{(-u)} \quad \Rightarrow \quad \frac{1}{f}=\frac{-1}{v}+\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{u}-\frac{1}{v}$$

We know that the focal length of a concave lens is negative, so the above equation will be changed to,

$1-f=1u-1v$

$\Rightarrow 1f=1v-1u$

(c) Magnification in = -1; v = +40 cm (real and inverted);
Nature of the lens = ?; Power of the lens, P = ?

$vu = m$

$\Rightarrow +40u = -1$

$\Rightarrow 40 = -u \Rightarrow u = -40$ cm

According to the lens formula:

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{f}=\frac{1}{40}-\frac{1}{-40}=\frac{1}{40}+\frac{1}{40}=\frac{2}{40}=\frac{1}{20}$$

f = +20 cm

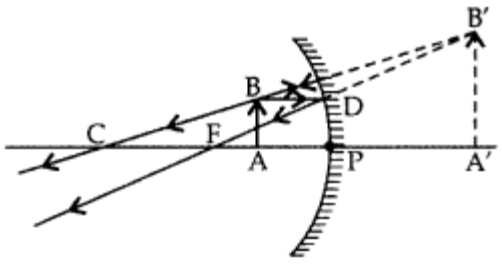
∵ f is +ve thus the lens is convex

$$P=\frac{1}{f(\text{metres})}=\frac{1\times 100}{20}=+5D$$

Since power of lens is positive, lens will be converging in nature.

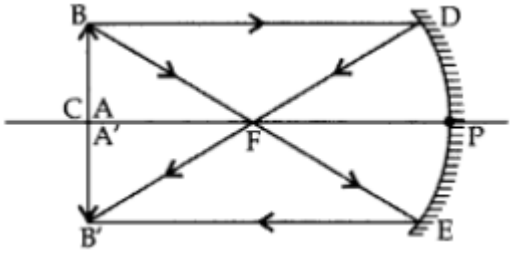
Question 25.
It is desired to obtain an erect image of an object, using concave mirror of focal length of 12 cm.
(i) What should be the range of distance of an object placed in front of the mirror?
(ii) Will the image be smaller or larger than the object? Draw a ray diagram to show the formation of image in this case.
(iii) Where will the image of this object be, if it is placed 24 cm in front of the mirror? Draw a ray diagram for this situation also to justify your answer.
Show the positions of the pole, the principal focus and the centre of curvature in the above ray diagrams. (2016 OD)

Answer:
In a concave mirror an erect image will be obtained when the object is placed between pole and focus of the mirror.
Focal length, f = 12 cm



(i) Therefore, the range of object distance is between 0 cm to <12 cm (from zero to less than 12 cm).
(ii) Image formed will be magnified, i.e., larger than the object.
(iii) If the object is placed at 24 cm in front of the mirror, it means that object is placed at 2f, i.e., at the centre of curvature (at C) of the mirror.

The real, inverted and same size (of the object) image will also be formed at 24 cm.



Question 26.
(a) Define optical centre of a spherical lens.
(b) A divergent lens has a focal length of 20 cm. At what distance should an object of height 4 cm from the optical centre of the lens be placed so that its image is formed 10 cm away from the lens. Find the size of the image also.
(c) Draw a ray diagram to show the formation of image in above situation. (2016 OD)

Answer:
(a) Optical centre of the lens. It is a point within the lens that lies on the principal axis through which a ray of light passes undeflected.

(b) f = -20 cm, h_1 = 4 cm, v = -10 cm, u = ?, h_2 = ?

$$\frac{1}{f}=\frac{1}{v}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{-20}=-\frac{1}{10}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{u}=-\frac{1}{10}+\frac{1}{20}$$

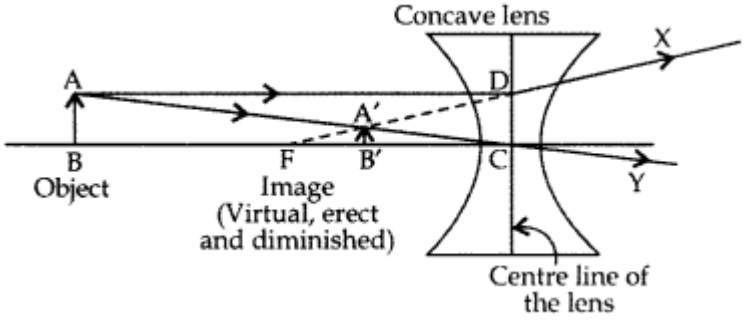
$$\Rightarrow \quad \frac{1}{u}=-\frac{1}{10}+\frac{1}{20} \quad \Rightarrow \quad \frac{1}{u}=\frac{-2+1}{20} \quad \Rightarrow \quad \frac{1}{u}=\frac{-1}{20}$$

∴ u = -20 cm
Now,

$\frac{h_2}{h_1}=\frac{v}{u}$

$\Rightarrow \frac{h_2}{4}=\frac{-10}{-20}$

∴ $h_2 = \frac{10}{20} \times 4 = 2$cm



Question 27.
(a) Define focal length of a spherical lens. (2016 OD)
(b) A divergent lens has a focal length of 30 cm. At what distance should an object of height 5 cm from the optical centre of the lens be placed so that its image is formed 15 cm away from the lens? Find the size of the image also.

Answer:
(a) The distance between optical centre and focus of the lens is called focal length of a spherical lens.
(b) Diverging lens: Concave lens
Focal length f = -30 cm
Object distance, u = ?
Image size, h_2 = ?
Height of the object, h_1 = 5 cm
Image distance, v = -15 cm
According to the lens formula:

$$1f=1v-1u$$

$$\frac{1}{-30}=\frac{1}{-15}-\frac{1}{u} \quad \Rightarrow \quad \frac{1}{u}=\frac{-1}{15}+\frac{1}{30}=\frac{-2+1}{30}=\frac{-1}{30} \quad \Rightarrow \quad u = -30 \text{ cm}$$

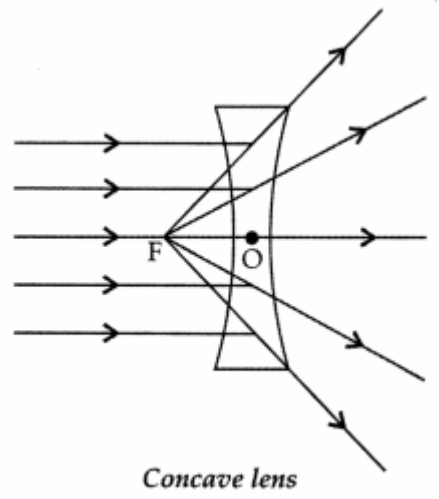
$$\frac{h_2}{h_1}=\frac{-v}{u} \quad \Rightarrow \quad \frac{h_2}{5}=\frac{-15}{-30} \quad \Rightarrow \quad h_2=\frac{5}{2}=2.5 \text{ cm}$$

Question 28.
(a) Define focal length of a divergent lens.
(b) A divergent lens of focal length 30 cm forms the image of an object of size 6 cm on the same side as the object at a distance of 15 cm from its optical centre. Use lens formula to determine the distance of the object from the lens and the size of the image formed.
(c) Draw a ray diagram to show the formation of image in the above situation. (2016 OD)
Answer:
(a)

- The principal focus of a diverging lens is a point on its principal axis from which light rays, originally parallel to the axis appear to diverge after passing through the diverging (concave) lens.
- The distance between pole and principal focus of a diverging lens is called the focal length.

In the given diagram OF is the focal length.

(b) Divergent lens (Concave lens)
Focal length, f = -30 cm;
Size of the object, h_1 = 6 cm
Image distance, v = -15 cm:
Object distance, u = ?
Size of the image, h_2 = ?



Concave lens

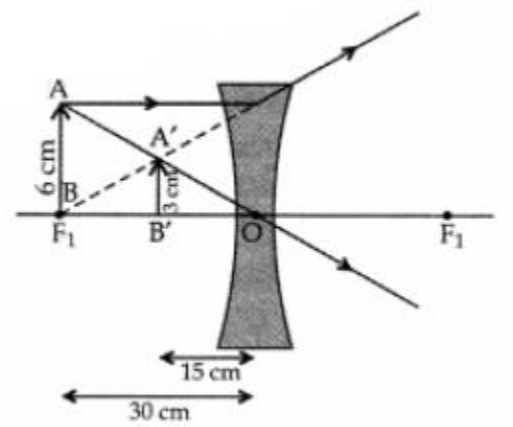
According to the lens formula:

$1f=1v-1u$

$$\frac{1}{-30}=\frac{1}{-15}-\frac{1}{u} \Rightarrow \frac{1}{u}=\frac{-1}{15}+\frac{1}{30}=\frac{-2+1}{30}=\frac{-1}{30} \Rightarrow u=-30\ \text{cm}$$

$$\frac{h_2}{h_1}=\frac{v}{u} \Rightarrow \frac{h_2}{6}=\frac{-15}{-30} \Rightarrow h_2=\frac{15}{30}\times 6=+3\ \text{cm}$$

(c) Diagram:



Question 29.

(a) To construct a ray diagram we use two rays which are so chosen that it is easy to know their directions after reflection from the mirror. List two such rays and state the path of these rays after reflection in case of concave mirrors. Use these two rays and draw ray diagram to locate the image of an object placed between pole and focus of a concave mirror.

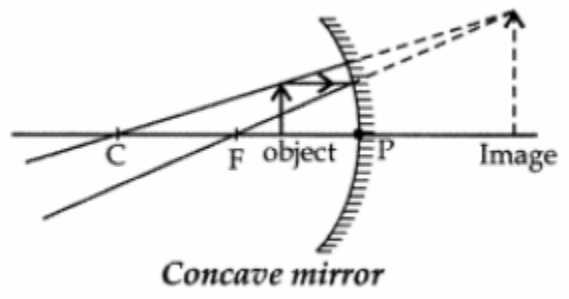
(b) A concave mirror produces three times magnified image on a screen. If the object is placed 20 cm in front of the mirror, how far is the screen from the object? (2017 D)

Answer:

(a) These two rays are:

(i) Ray of light parallel to principal axis, passes through point F of concave mirror

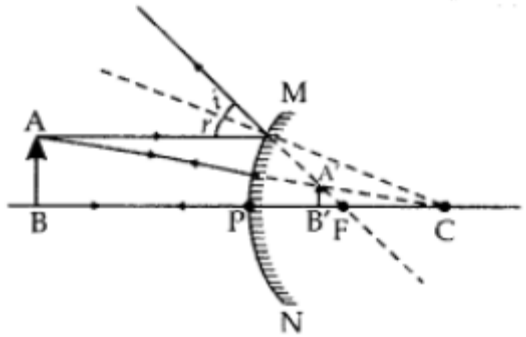
after its reflection.
(ii) Ray of light passing through point C of the mirror, is reflected back on the same path after reflection from the mirror.
Image is erect, virtual and magnified.



(b) m = -3, u = -20 cm, v = ?
$m = -\frac{v}{u} \Rightarrow -3 = -\frac{v}{-20} \Rightarrow v = -60$ cm
Distance between the screen and the object distance = [-60 – (-20)] = -40 cm
So, the screen is at a distance of 40 cm from the object.
Minus sign is only as Per sign conventions.

Question 30.
(a) If the image formed by a mirror for all positions of the object placed in front of it is always diminished, erect and virtual, state the type of the mirror and also draw a ray diagram to justify your answer. Write one use such mirrors are put to and why?
(b) Define the radius of curvature of spherical mirrors. Find the nature and focal length of a spherical mirror whose radius of curvature is +24 cm. (2017 OD)

Answer:
(a) This mirror is Convex mirror:
Such mirrors are used as rear view mirror in automobiles, as convex mirror gives erect, and wider range of view of objects coming behind the automobile.



(b) Radius of curvature of a mirror is the distance between 'P' point (pole) and 'C point (centre of curvature) of a spherical mirror.
$f = r2$
So, $f = 242$
∴ f = +12 cm and this mirror is a concave mirror.